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# ILLINOIS

# State Geological Survey

BULLETIN NO. 8

## Year-Book for 1907

H. FOSTER BAIN,

DIRECTOR.


URBANA
UNIVERSITY OF ILLINOIS
1907

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PHILLIPS BROS., STATE PRINTERS
1908.

## STATE GEOLOGICAL COMMISSION.

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GOVERNOR C. S. DENEEN, *Chairman.*

PROFESSOR T. C. CHAMBERLIN, *Vice-Chairman.*

PRESIDENT EDMUND J. JAMES, *Secretary.*

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H. FOSTER BAIN, *Director.*

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# LETTER OF TRANSMITTAL.

STATE GEOLOGICAL SURVEY,
UNIVERSITY OF ILLINOIS, April 22, 1908.

*Governor C. S. Deneen, Chairman and Members of the Geological Commission:*

GENTLEMEN—I submit herewith material forming the year book of the State Survey for 1907, with the recommendation that it be printed as Bulletin No. 8. It includes the record of a notably successful year's work which is fully reviewed in the administrative portion of the report. The accompanying papers present in abstract or in preliminary form many of the important results of the year's surveys. More complete reports are being prepared and will be submitted for publication as rapidly as possible.

The large amount of geological work accomplished was made possible by the cutting down of the topographic allotment consequent on a partial failure of Congressional appropriations. It is to be hoped that in the near future funds may be available for at least an equivalent amount of geological work and no less of topographic. Both classes of surveys are in great demand throughout the State and should be pushed as rapidly as the finances of the State will permit.

Very respectfully,

H. FOSTER BAIN,
*Director.*

# ADMINISTRATIVE REPORT FOR 1907.

(BY H. FOSTER BAIN, DIRECTOR.)

## Contents.

## INTRODUCTION.

*Organization*—For the year 1907 the Geological Survey was organganized in three sections; *a*, geologic; *b*, topographic and *c*, drainage. The geologic work was under the immediate direction of the director. The topographic surveys were carried on under Mr. W. H. Herron, Geographer in charge of the central section, U. S. Geological Survey. The drainage work was under the general charge of the director, but Mr. Herron and Mr. E. W. McCrary courteously relieved him of much of the direct responsibility for the work.

The work of the year, as shown in detail in the following pages, involved the extension of the topographic surveys to cover important portions of the coal fields, oil fields and lake shore, the organization of the special survey of bottom lands subject to overflow, and the vigorous prosecution of the general investigation of the mineral resources of the State.

As heretofore the relations between the State Geological Survey and other organizations have been close. With the U. S. Geological Survey there has been coöperation, as detailed later, in the topographic surveys, the drainage surveys, the study of the coal fields, the clays and quarry products, the water resources of the State and the collection of mineral statistics. With the Internal Improvement Commission and the U. S. Department of Agriculture special coöperation has been arranged covering the survey and study of the rivers of the State. With the Engineering Experiment Station, the graduate school and the department of chemistry of the University of Illinois, special chemical studies of coal have been carried on throughout the year. With the State Water Survey and other organizations, as detailed in the administrative report for 1906, coöperative studies of the water of the State were carried on up to July 1st. After that date less formal but very helpful assistance was given us by the Water Survey. The University of Chicago, the University of Illinois, Northwestern University and Augustana College authorities have also been extremely helpful in arranging satisfactory hours or leaves of absence for members of their instructional forces to carry on survey work. Numerous firms and individuals have been of material assistance and acknowledgment will be made in the individual reports as issued. Mention should, however, be made especially of the Fuel Engineering Company and of Mr. A. Bement of Chicago for assistance and courtesies received. To these and the many others who have assisted the officers of the survey in their work our best thanks are offered.

*Personell*—In the course of the year there were numerous changes in the working force of the survey. In June Mr. F. B. Van Horn, Assistant Geologist in general charge of the office, resigned to accept an important position with the U. S. Geological Survey at Washington, D. C., with him went Mrs. Sadie A. Van Horn, stenographer. The office work was temporarily assumed by G. R. White but later the places were filled by the appointment of Samuel Abrams, stenographer and G. M. Wood, clerk. On July 1st, Mr. Frank W. DeWolf assumed the position of Assistant State Geologist, being detailed by courtesy of the director of the U. S. Geological Survey for duty in connection with our coöperative studies of the coal fields. Mr. DeWolf has not only had charge of the coal surveys but has handled many of the details of the regular office work and has been in full charge during temporary absences of the director. Messrs. Rolfe, Grant and Salisbury have continued to serve as consulting geologists and Messrs. Parr and Bartow as consulting chemists as detailed elsewhere. Messrs. Weller, Savage and J. A. Udden have served various parts of the year as geologists. Messrs. Jon Udden, G. H. Cady, H. H. Barrows, J. C. Carman, J. W. Goldtwait, J. C. Jones, N. M. Fenneman, A. C. Trowbridge, I. J. Broman and A. J. Ellis, have served as field assistants. Mr. R. C. Purdy, ceramist, resigned from the University in June to accept a position in Ohio State University, and was succeeded by A. V. Bleininger. Messrs. J. K. Moore and H. R. Straight served a short time as special agents in the collection of mineral statistics. Mr. E. F. Lines Assistant Geologist, has been on duty half the year in connection with certain studies of clays being carried on in coöperation with the U. S. Geological Survey. Mr. E. F. Burchard, also of the U. S. Geological Survey, spent a few months in the study of quarry products and road materials for the State Geological Survey and the State Highway Commission. Mr. David White of the U. S. Geological Survey spent a short season in the State. Messrs. Carman, Ellis, Broman and Fenneman have completed the work assigned to them. The other field assistants are engaged in writing up their reports.

A number of the State mine inspectors have, as heretofore, assisted in the work of survey. Messrs. James Taylor and Tom Moses in particular, have devoted time to mine sampling and similar work. Mr. W. F. Wheeler served as chemist throughout the year. In the coöperative coal studies and in certain analytical work Messrs. Justa Lindgren, Perry Barker, C. K. Francis, N. D. Hamilton, Dean Burns and R. F. Hammer were also employed a portion of their time.

In the topographic work the men employed were Mr. W. H. Herron, geographer in charge, Messrs. J. R. Ellis, W. J. Lloyd, J. F. McBeth and H. L. McDonald, topographers; Messrs. E. W. McCrary, Lee Morrison and W. A. Gelbach, junior topographers; W. H. Snyder, recorder; Messrs. Henry Bucher, Donald Wilhelm, A. J. Hendley, G. L. Gross, W. L. Harrison, E. L. Hain and A. C. Wood, levelmen; Messrs. J. W. Lowell, Jr., F. W. Crisp, G. R. Hoffman, J. S. Rohrer, R. C. O. Matheny and S. K. Atkinson, traversmen. In addition rodmen, chainmen and laborers were temporarily employed as needed.

From July to December Mr. Herron made his headquarters at Urbana to the very great advantage of the State work. He courteously undertook in addition to his regular work the organization of the special drainage surveys, for which we are under great obligations to him. A number of members of the regular topographic force was employed in this work. In addition Messrs. P. E. Fletcher, John Fletcher and James E. Tichenor with usual complement of rodmen and laborers were employed.

The present organization of the survey is as follows:

### COMMISSIONERS.

Governor C. S. Deneen, Chairman.
Professor T. C. Chamberlin, Vice Chairman.
President E. J. James, Secretary.

### ADMINISTRATIVE WORK.

H. Foster Bain, Director.
Samuel Abrams, Clerk.

### GEOLOGICAL SECTION.

F. W. DeWolf, Assistant State Geologist.
Professor R. D. Salisbury, Consulting Geologist.
Professor U. S. Grant, Consulting Geologist.
Professor C. W. Rolfe, Consulting Geologist.
Professor S. W. Parr, Consulting Chemist.
Dr. Edward Bartow, Consulting Chemist.
Dr. Stuart Weller, Geologist.
Professor T. E. Savage, Geologist.
Professor J. A. Udden, Geologist.
Professor A. V. Bleininger, Ceramist.
Mr. E. F. Lines, Assistant Geologist.
Mr. W. F. Wheeler, Chemist.
Mr. H. H. Barrows, Field Assistant.
Dr. J. W. Goldthwait, Field Assistant.
Mr. J. C. Jones, Field Assistant.
Mr. A. C. Trowbridge, Field Assistant.
Mr. G. H. Cady, Field Assistant.
Mr. Jon Udden, Field Assistnt.

### TOPOGRAPHIC SECTION.

W. H. Herron, Geographer in Charge.
W. J. Lloyd, Topographer.
J. F. McBeth, Topographer.
J. R. Ellis, Topographer.
H. L. McDonald, Topogrâpher.
E. W. McCrary, Junior Topographer.
Lee Morrison, Junior Topographer.
W. A. Gelbach, Junior Topographer.

### DRAINAGE SECTION.

W. H. Herron, Geographer.
E. W. McCrary, Assistant Engineer.
G. M. Wood, Clerk.

*Kaskaskia River Survey:*

P. E. Fletcher, Resident Engineer.
John Fletcher, Levelman.

Lee Morrison, Topographer.
S. K. Atkinson, Traversman.
R. C. O. Matheney, Traversman.

*Big Muddy River Survey:*

J. S. Rohrer, Topographer.
G. L. Gross, Levelman.

*Embarass River Survey:*

James E. Tichenor, Topographer.

## Geological Section.

*General Stratigraphy*—A correct knowledge of the stratigraphy of the State is fundamental to any study of its mineral resources. Whether it be coal, clay, stone, water, oil, gas or any other mineral, we must know the character, thickness and relations of the rocks prior to any certain determination of rock content or structure. For this reason a considerable portion of the funds of the survey continue to be devoted to stratigraphic studies. These are under the general direction of Dr. Stuart Weller of the University of Chicago who devotes to the work such portion of his time as can be spared from academic duties. He is mainly assisted by Mr. T. E. Savage of the University of Illinois and by Mr. Jon Udden, though all the field men contribute to work.

In 1907 Dr. Weller's personal work involved the continuation of his studies of the Mississippian formation of southern Illinois and a preliminary statement of his results so far as relates to the Salem limestone, appears in later pages. In views of the scientific and economic importance of the Mississippian rocks it is planned for Dr. Weller to continue these studies through at least another season. In the meantime he has found time to visit other portions of the State in company with members of the survey and has contributed notably to our knowledge of these areas.

Mr. T. E. Savage devoted his field season to a study of the pre-Mississippian rocks of southwestern Illinois, a complex and little studied stratigraphic section. His laboratory work was done at Yale University under the direction of Professor Charles Schuhert. A preliminary statement of his results, which prove to be of unexpected scientific importance, appears in later pages.

In connection with the work on coal, clay, cement materials, etc., notes of large value form a stratigraphic point of view are being rapidly accumulated. The detailed structural maps by Messrs. DeWolf and J. A. Udden published in this volume are believed to be especially important and it is to be remembered that these results while not so striking as certain others are even, in some cases, so immediately useful, are in the end of the highest economic importance as well as fit contributions by our State to scientific advancement.

The demand for Dr. Weller's bulletin containing a preliminary geological map of the State (Bulletin No. 1) having become so great that but a few copies remained available for distribution, a new edi-

tion was prepared and distributed.* An abstract of the more important changes in the text is given in this volume. The supply available for gratuitous distribution was exhausted within a month of its publication and since that sales have been steady. This perhaps sufficiently indicates the interest with which it has been received.

*Coal*—Since July 1st the special studies of the coal fields have been under the immediate direction of Assistant State Geologist DeWolf. These studies have been of two kinds: (1) Field surveys; (2) Laboratory investigation. The first have been carried out in close coöperation with the U. S. Geological Survey, which organization has borne one-half the expense of the work. The second has been under the laboratory direction of Professor S. W. Parr, consulting chemist and has involved coöperation with the University proper, the Engineering Experiment Station and the Fuel Engineering Company.

The field surveys of the year have included the extension of the detailed work in the southern part of the State westward from the Eldorado, across the Galatia and into West Frankfort quadrangle, with preliminary work to and including Murphysboro. This work was carried out by Mr. DeWolf with the assistance of Mr. A. J. Ellis. A preliminary statement of results appears in later pages of this report.

The work near East St. Louis has been written up by Dr. N. M. Fenneman and a report is nearly ready for submission. Dr. J. A. Udden, assisted by Mr. I. J. Broman, has carried the detailed field work eastward across the Belleville and Breese quadrangles. A preliminary report on this area is submitted with this and a fuller one is in preparation. In the Springfield district the field work of the past season was directed rather to a study of the surface features, by Mr. J. C. Jones. It is planned in 1908 to complete the underground stratigraphic studies as far as present data will allow and to prepare a report. In the Peoria district additional field work was carried on by Dr. J. A. Udden and a very complete report has been prepared for publication. Certain interesting portions are abstracted for immediate publication in this year book and appear in later pages.

In general Mr. DeWolf has made reconnoissance studies over a considerable portion of the field outside the areas now being surveyed in detail, and Mr. David White has extended his very valuable researches upon the paleobotanic horizons, particularly in the equivalents of the Pottsville group of the east. The work of Messrs. G. H. Cady and Jon Udden, noted elsewhere, in tracing out certain coal measure limestones has also measurably advanced our knowledge of the general stratigraphy of the field. It is expected that in 1908 these general studies in particular, will be rapidly expanded with a view to the early publication of a general preliminary report upon the coal fields of the State.

The laboratory work of the year has involved, (1) the chemical analysis of coals mined in the areas being surveyed in detail and (2) general studies of the composition of our coal and conditions which affect its heat value. A number of analyses are published in the detailed reports herewith submitted. Several brief papers also appear

*State Geol. Survey, Illinois, Bull. 6. Price 45 cents.

in which are preliminary statements of results obtained on the deterioration of coals in the laboratory and in storage. These studies are still being carried on and the results here given are of preliminary value only. Later results will be based on much fuller and more accurate determinations. It is believed none the less that the results here announced are truly significant and warrant publication. The analyses except where otherwise stated, are based upon mine samples collected by Messrs. DeWolf, Wheeler and Moses, or car samples collected at the mine or university by Mr. Wheeler, Mr. Lindgren or other members of the Engineering Experiment Station staff. The commercial samples were furnished by the Fuel Engineering Company of Chicago and are in all cases based upon actual deliveries in large quantity. The figures given by Mr. Bement are based upon coal passed on by him in the course of a large private practice.

It has been found impracticable at the present time, mainly owing to limitations of funds, to undertake certain highly desirable studies of the technology of the mining industry and of the geographical distribution of markets for Illinois coals. It is believed that much good would result from investigations along these lines and that certain portions of the work are well within the proper limits of the State Geological Survey. It is now well known that there is, under present commercial conditions, an enormous waste in the mining of Illinois coal. In individual districts this has been estimated to amount to as much as 60 per cent, though of course such losses are not general. It would, however, probably be safe to say that in very many places 40 per cent of the coal in the ground is left unmined or is ruined in the process of mining. In addition, the methods of mining introduced in recent years have greatly increased the production of fine sizes and have also, seemingly, increased the danger to life and property in the mines. The causes for all these losses are complex, and it is not to be supposed that either operators or miners willingly submit to them. Neither is it to be expected that the losses of life and property can be entirely done away with. At the same time experience has abundantly proven that careful and impartial investigations of such conditions will point the way to the remedying of some at least of the abuses, and in view of the enormous importance of the subject to the State and the public at large, such studies are believed to be amply warranted. Fortunately it now seems likely that the United States government will take up a general study of the most complex of the problems—the causes and preventions of explosions and other accidents in mines. This still leaves, however, many important local problems to be investigated; problems that are in no way national, and it is hoped that the State Survey may be given the means for taking them up.

The expansion of markets for Illinois coal is a matter of vital importance to the coal industry and indirectly to the people of the entire State. One of the most important means of promoting this expansion is by removing certain misapprehensions as to the quality of the coal and the pointing out of better means of burning, so as to increase its efficiency and decrease the smoke produced. This work has been taken

up vigorously by the Engineering Experiment Station, which has published excellent bulletins on "How to Burn Illinois Coal Without Smoke" and other similar subjects.* In addition to this valuable work, there should be investigations of the actual markets for the different grades of coal and of possible enlargements of these markets. There are large areas to the northwest within which Illinois washed coals might profitably supplant eastern coals now being sold. There are other areas to the south and west where, with proper organization of transportation agencies, even in advance of improvement of the rivers, trade territory could be gained. Any widening of the market would be of large benefit to the local industry, particularly if the summer market could be increased. For this reason the studies now under way relating to weathering of coal and coal storage are especially important.

*Clay*—As heretofore, the laboratory investigation of our clays has been carried on in coöperation with the Department of Ceramics of the University of Illinois, with Professor C. W. Rolfe as consulting geologist. On July 1 Mr. R. C. Purdy was succeeded by Mr. A. V. Bleininger as ceramist. At the same time Mr. E. F. Lines of the United States Geological Survey was detailed for special coöperative work on clays.

The laboratory work on paving brick has been completed, and the report has been undergoing revision by Messrs. Rolfe, Purdy and Talbot. It is now essentially ready for publication.

The report includes the following chapters:

Geology of Clays; by C. W. Rolfe.
Geological Distribution of Paving Brick Clays in Illinois; by C. W. Rolfe.
Qualities of Clays suitable for making Paving Brick; by Ross C. Purdy.
Qualities of High Grade Paving Brick and the Tests used in Determining Them; by A. N. Talbot.
Test of Paving Brick Clays.
Clays studied which are suitable for making Paving Brick, with tables showing their properties.
The Construction and care of Brick Pavements; by Ira O. Baker.

Certain of these chapters have been given advance publication and it is expected that the whole report will be printed very shortly.

Mr. Lines has devoted his time mainly to a study of the Colchester fire clay of the western part of the State. Mr. David White has shown that this is the stratigraphic equivalent of the famous Cheltenham clay of St. Louis, Missouri. This opens large possibilities for an important fire clay industry in western Illinois, and further studies on the extent of the deposit and its quality from point to point are now under way. Mr. Lines has also made important observations on the shrinkage of certain clays during drying and has compiled a directory of the clay industry of the State, which is published in this volume.

In coöperation with Mr. Burchard of the Technological Division of the U. S. Geological Survey, Mr. Lines collected materials and notes on the bricks and brick clays of the Chicago district. These collections are now being tested.

*For copies of bulletins, circulars, etc., address Engineering Experiment Station, Urbana, Illinois.

Mr. T. R. Ernest has taken up the laboratory study of the silica deposits of the southern part of the State with a view to their more complete utilization. Certain interesting preliminary results are published in this year book. The work is, however, incomplete, and it must be left to a later time to present an adequate study of the whole subject.

*Cement Materials*—It has long been known that Illinois contained large supplies of unutilized material probably valuable for the manufacture of Portland cement. In 1907 a special effort was made to locate, sample and study these deposits. The organization of the work was placed under Dr. U. S. Grant, consulting geologist, who after carefully planning it and starting the field work of the various men, was obliged to withdraw to take up other studies. The actual field work was therefore carried on by Messrs. G. H. Cady, Jon Udden, T. E. Savage, Stuart Weller, F. W. DeWolf, J. A. Udden and E. F. Burchard. Notes and samples were collected from seventy-five localities and 112 analyses were made under the direction of Professor Parr by Messrs. Lindgren, Wheeler and Hammer.

An especial effort was made to find deposits of non-magnesian limestone of suitable thickness and situation as regards cover, transportation facilities, etc., to afford the calcareous element in the cement. It was felt that this was likely to be the limiting factor in the location of any new plant. The analyses made, together with those made in 1906 and already published,* afford fairly satisfactory data on these points. These analyses and accompanying notes are being studied by Mr. Bleininger preliminary to similar testing of the nearest available clay deposits and the preparation of a preliminary bulletin on the cement materials of the State. In the meantime in succeeding pages Messrs. Cady and Jon Udden give detailed observations upon two important districts within which material is available, and it may be stated that the preliminary work confirms the belief that great quantities of suitable rock admirably situated as regards fuel and transportation, are to be found within the State.

*Quarry Products*—Notes on the location of quarries and quarry sites, the thickness of stone and stripping and the general character and availability of the material are being kept by all members of the survey. In addition, and in coöperation with the State Highway Commission, Mr. E. F. Burchard, on detail from the U. S. Geological Survey, has devoted some time to the study of quarries and quarry sites. Special visits were made to and detailed observations are now available on twenty sites. It is hoped to extend this work over the State as rapidly as possible.

In connection with his work for the Technological Division of the U. S. Geological Survey, Mr. Burchard has also made a study of structural materials available in the Chicago district. A preliminary report has been issued† and further studies are now under way. In the latter the State Survey, through Mr. E. F. Lines, has been coöperating.

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*Van Horn, F. B., Limestones for Fertalizer, State Geol. Survey, Illinois, Bull. 4, pp. 177-183
†U. S. Geological Survey, Bull. 340. See also this volume.

In connection with Dr. Weller's work on the Mississippian, numerous quarry sites have been studied. Attention is especially invited to his paper in this volume on the Salem limestone, because this is the equivalent of the famous Bedford stone of Indiana. Dr. Weller finds the formation widespread and well developed in certain parts of the State. With regard to its development in Monroe county, he makes the following significant statement:

"At some points certain beds of limestone might be satisfactorily and profitably developed as a building stone. The Iron Mountain Railroad, running the entire length of the county between the bluffs and the river, would furnish good transportation facilities. The locality where the formation seems to be most favorably situated for quarry purposes is about one mile above the Randolph county line, in the point of the bluff west of the road, which runs in a northerly direction to the village of Renault. At this point the rock occurs in more than usually heavy beds, it is apparently uniform in texture and color and resists the action of weathering. Furthermore, it is not covered at this point by heavy ledges of superjacent St. Louis limestone and a large quarry might be opened with but a minimum amount of stripping. Careful tests would be necessary to determine whether the rock at this point would be equal for purposes of construction to the celebrated 'Bedford stone' of Indiana, but the superficial examination of the locality would seem to indicate this to be the case."

*Oil and Gas*—The developments of 1907 as regards these important materials are fully detailed on later pages. It is to be regretted that the absence of suitable topographic maps and the pressure of other duties has prevented as thorough study as the importance of the subject demands. To remedy the first defect, topographic mapping was taken up in the Bridgeport field and preliminary level lines run in adjacent quadrangles. Topographic mapping was also expanded in the western and southern parts of the State in areas not improbably of ultimate value in this connection. Such drill records as could be obtained were collected and studied. Much, however, remains to be done, and it is especially important that better means be devised for collecting and preserving deep well records. These are so important from the points of view of water supplies, coal beds and general underground stratigraphy, as well as of oil and gas, that it is hoped it will shortly prove possible to detail one man to this particular work.

*Water Resources*—The importance of further geological knowledge in connection with the study of the water resources of the State is fully appreciated. Within the year a special report on the water resources of the East St. Louis district was published.* An abstract of this report is published in succeeding pages. The general coöperative work on the quality of water in the streams of the State, entered into in 1906 with the State Water Survey, the Engineering Experiment Station and the U. S. Geological Survey,† was carried to completion and the results are now undergoing study. In connection with the detailed areal work, studies of underground structure and waters were made and results for the Peoria district are published elsewhere

*Bulletin 5, State Geological Survey.
†State Geol. Survey, Bull. 4, pp. 17-21.

in this volume. Dr. Edward Bartow continued his work in the preparation of a bulletin on the mineral composition of the underground waters of the State and the manuscript of the report is now nearly complete.

Numerous individual analyses and tests of deep waters were made for the survey by Dr. Bartow. The most interesting result was the discovery in southeastern Illinois of a brine of sufficient strength to be of possible commercial value. This suggests the advisability of frequent tests of the salt waters found in the oil region, with the hope of reviving the formerly important salt industry of the State.

*Mineral Statistics*—The collection of statistics showing output and value of the mineral products of the State was continued in coöperation with the Division of Mineral Resources of the U. S. Geological Survey. Mr. F. B. Van Horn prepared and published the figures for the year 1906,* which showed a total value of raw materials or materials in the first stage of manufacture, of $68,296,908. The corresponding figures for 1907 are $92,364,763. If to this be added the pig iron and other materials produced in the State from ores mined elsewhere, the total would be increased to $121,188,306 in 1906 and $154,128,473 in 1907.

*Educational Bulletins*—The first of the bulletins designed especially for the use of the schools was sent to the printer within the year† and an abstract is published in this volume. The work of completing similar reports and preparing others has been carried forward vigorously under the general direction of Professor R. D. Salisbury of the University of Chicago. The following bulletins are complete, or essentially complete, and will shortly be ready for publication:

The Mississippi valley between Savanna and Davenport, by J. Ernest Carman. Prepared in coöperation with the Iowa Geological Survey.

Physical features of the Desplaines valley, by James Walter Goldthwait.

Physical geography of the East St. Louis district, by N. M. Fenneman.

The work of the year involved in addition the field work for similar reports on the Springfield quadrangle by J. C. Jones, the Wheaton quadrangle by A. C. Trowbridge and the middle Illinois valley by H. H. Barrows. Brief preliminary notes from these bulletins appear in later pages.

*Bureau of Information*—As heretofore, a large amount of time and effort of members of the survey has gone into the work of answering personal or written inquiries of all kinds regarding the mineral resources of the State. These come from land owners, investors, railways, cities and towns, commercial associations, teachers and pupils and, in fact, from all classes of people both within and without the State. The aggregate number is very large and the number of inquiries per day is constantly increasing. This work is believed to be an important function of the survey, though it necessarily hampers the larger and systematic study of the State's resources.

It is hoped by preparing and distributing special reports to gradually reduce the amount of time which need be devoted to each inquiry, but

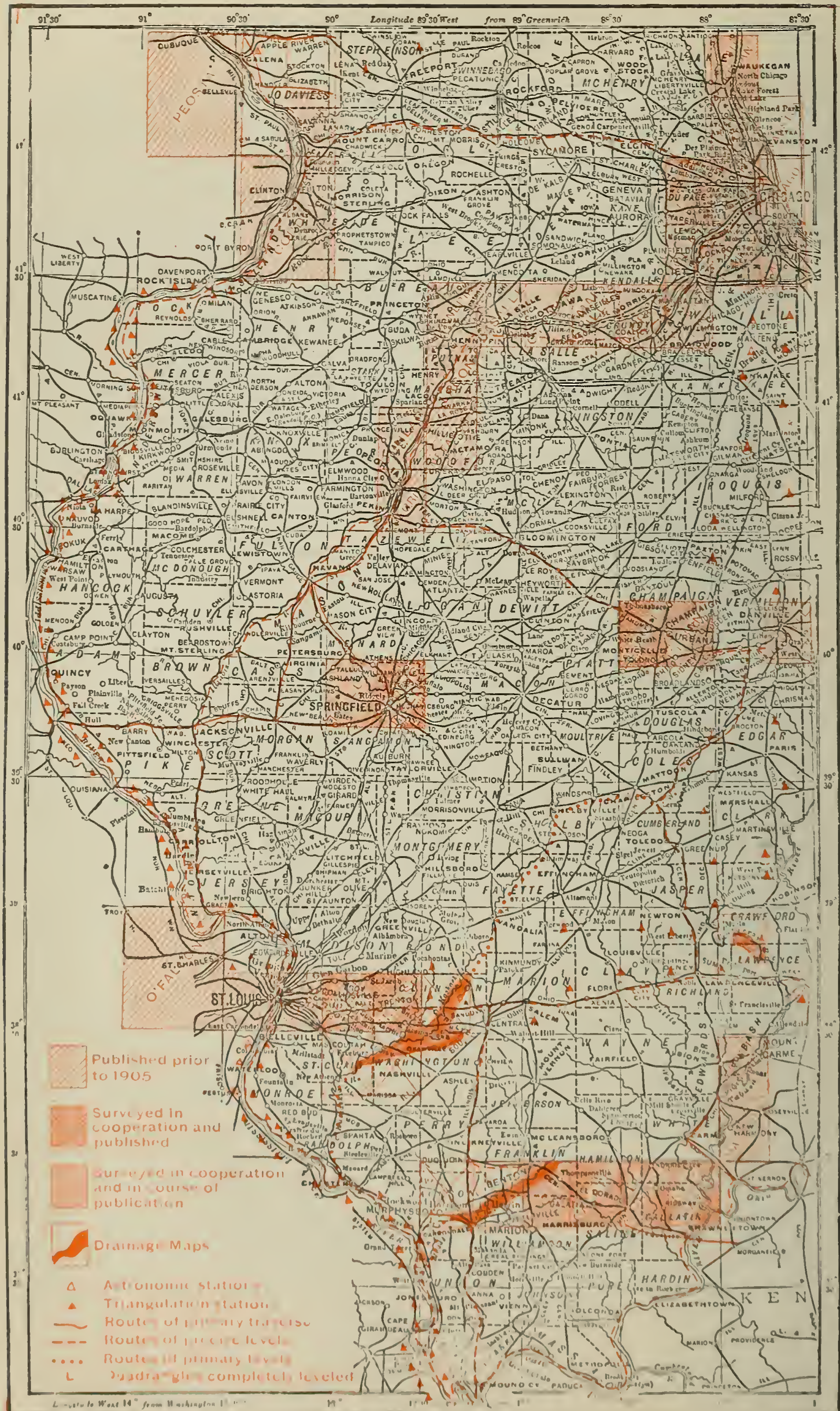
*Circular No. 2, State Geological Survey. Postage 2 cents.

†Physical Geography of the Evanston-Waukegan Region; by W. W. Atwood and J. W. Goldthwaite, Bull. No. 7, State Geological Survey.

for the present nearly every letter presents a new problem. The existing literature on the geology of Illinois is badly scattered, and the data now accumulating in the form of drill records, letters and note books must be constantly indexed in order to be available. This is particularly necessary where so many of the members of the survey devote but a portion of their time to the work and do not make headquarters at the main office. Index cards have therefore been provided and an effort is being made to keep the new information as fully indexed as possible. As an aid to this, a series of State maps are being prepared, upon which are indicated by means of tacks all deposits or industries located or studied by the members of the survey.

An important adjunct to this would be a complete bibliography of the geology of the State, but help and funds for this work have not so far been available. Such a bulletin was undertaken by Mr. Lewis and later carried on by Mr. Van Horn, but since they left the survey the work has remained incomplete. This is particularly to be regretted, as a bibliography would be of large general service.

The survey has numerous requests for analyses and tests of materials of real or supposed value from all parts of the State. In many cases it is not necessary to make an analysis in order to determine the value of the material, and in all such instances the results of a physical examination are cheerfully and promptly furnished the inquirer. In other instances an analysis is necessary; or, in the case of clays particularly, a burning test. Such laboratory work is costly, and it is desirable not to incur this expense except on samples which are truly representative of a commercially important amount of material. Sampling and field concurrence are quite as important as the results of the laboratory test and call for just as special knowledge. For these reasons, together with the fact that any other course would permit the whole appropriation to be used up by any citizen for private chemical work, or even for work of doubtful value, the survey has been forced to decline to make any analyses or laboratory tests on miscellaneous materials sent in by correspondents. Wherever the material submitted or the note on its occurrence indicates something of probable general value, a record of the locality is made and the first time any of the survey men can, in the course of their regular work, visit and sample the deposit, it is done. While this occasionally leads to individual disappointment, it seems to be the only plan consistent with the general purpose of the survey; a systematic study of the mineral resources of the State, and the present size of its appropriations. As the special reports upon the individual areas and subjects are completed and become available, citizens will more and more have the data upon which to answer their own inquiries. In the meantime the survey welcomes letters of inquiry and notes on the occurrence of minerals and rocks and, subject to the restrictions noted above, will gladly furnish all information available. The reports already issued by the survey are listed elsewhere.




Map showing progress of Topographic and Drainage Surveys.

## Topographic Section.

(By W. H. Herron.)

The progress of the coöperative topographic surveys is illustrated in plate 1 and in the following table, which shows the localities in which work in Illinois was done during the season of 1907, and also gives a summary of results for the year:

| Locality. | Square miles of topography. | Primary traverse miles. | Secondary traverse miles. | Primary levels miles. | Secondary levels miles. |
|---|---|---|---|---|---|
| Herrin | 131 | ........ | 751 | 53 | 567 |
| West Frankfort | 235 | ........ | 189 | ........ | 854 |
| Okawville | 69 | 69 | 785 | 40 | 124 |
| Hardinville | 93 | 72 | 926 | 99 | 676 |
| Murphysboro | ........ | ........ | 748 | 66 | ........ |
| New Athens | ........ | 43 | 909 | 122 | 140 |
| Carlyle | 77 | 53 | 945 | 97 | 275 |
| Tallula | 15 | ........ | ........ | ........ | ........ |
| Totals | 620 | 237 | 5,253 | 477 | 2,636 |

The areas surveyed are naturally grouped into three localities—that in the southeastern portion of the State, under the general direction of Mr. J. F. McBeth; that in the southern part, in charge of Mr. W. J. Lloyd; and the southwestern part, under the supervision of Mr. E. W. McCrary. The primary control party, which operated in all three localities, was in charge of Mr. J. R. Ellis.

The following is the personnel of the organization in each locality:

*Southeastern*—J. F. McBeth, topographer in charge; H. L. McDonald, topographer; Henry Bucher, levelman; Donald Wilhelm, levelman; A. J. Hendley, levelman; J. W. Lowell, Jr., traversman; B. K. Babbitt, rodman; Mack McCreery, rodman; W. R. Emmons, rodman; James Stoltz, rodman.

*Southern*—W. J. Lloyd, topographer in charge; Henry Bucher, primary levelman; A. J. Hendley, secondary levelman; G. L. Gross, secondary levelman; W. L. Harrison, secondary levelman; F. W. Crisp, traversman; G. R. Hoffman, traversman; J. S. Rohrer, traversman; B. K. Babbitt, rodman; Percy Kimmel, rodman; Donald Wilhelm, rodman; C. P. Gross, rodman; Sidney Moore, rodman.

*Southwestern*—E. W. McCrary, topographer in charge; W. A. Gelbach, junior topographer; Lee Morrison, junior topographer; E. L. Hain, levelman; A. C. wood, levelman; R. C. O. Matheney, traversman; S. K. Atkinson, traversman; F. W. Crisp, Traversman; G. R. Hoffman, traversman; J. R. Lowell, rodman; W. H. Herron, rodman; Percy Kimmel, rodman; Charles Schulze, rodman; Mack McCreery, roman; J. W. Wilson, rodman.

*Primary Control*—J. R. Ellis, topographer; W. H. Snyder, recorder; R. H. Hawkins, rodman; G. B. McNair, chainman; C. M. McLean, chainman; E. F. Reiss, chainman; J. Boyd, laborer.

During the progress of the work on the Hardinville, West Frankfort and Herrin sheets, about thirty-four square miles of drainage survey work was accomplished under the direction of the topographers in charge, this work being divided as follows:

Hardinville quadrangle, by James E. Tichenor........ 7 sq. miles
West Frankfort quadrangle........................... 24 sq. miles
By J. S. Rohrer, 20 sq. miles.
By G. L. Gross, 4 sq. miles.
Herrin quadrangle, by G. L. Gross.................... 3 sq. miles

About thirty-two miles of precise levels were run to complete one of the circuits in the eastern part of the State.

The following table shows the expenditures during the season:

| | | |
|---|---|---|
| Balance January 1, 1907 | | $ 2,411.63 |
| Appropriation July 1, 1907 | | 16,000.00 |
| Total amount available for 1907 | | $18,411.63 |
| Expended in 1907: | Office, $ 1,790.76; | |
| | Field, 13,326.69 | 15,117.45 |
| Unexpended balance December 31, 1907 | | $ 3,294.18 |

The office expenditures indicated were from the unexpended balance of last year, and the work consisted of the completion in the office of maps of the previous season. It will be noted from the table that a large proportion of the funds during the field season were applied to extension of control preparatory to the sketching of these sheets in 1908.

The Tallula and West Frankfort were the only quadrangles entirely finished during the season. It is expected, however, that during the field season of 1908 all the sheets mentioned will be completed and ready for publication the following spring. The sketching on the Herrin and Hardinville sheets is more than half completed and will be finished in the early part of the field season.

## Drainage Surveys.

In response to a very general demand, the Forty-fifth General Assembly made an appropriation of $15,000 to the State Geolgical Survey to take up the survey and study of the bottom lands of the State subject to overflow. In accordance with this enactment, a special section has been organized. This is, for convenience, called the Drainage section. For the first year no attempt was made to cover a large area, it being thought more important to develop the most satisfactory methods of work and to carefully coördinate all the agencies, State and national, which might legitimately be asked to assist. As a result of repeated conferences, a State Committee on Waterways Reclamation has been organized, including representatives of the State Geological Survey, the Internal Improvement Commission and the U. S. Department of Agriculture. The work of this committee is detailed elsewhere in this report.

The task of making the maps of the lands in question was assigned to the State Survey, which promptly arranged to carry on this work in connection with the coöperative topographic survey under Mr. W. H. Herron. By this means trained men become immediately available, and the use of instruments, etc., furnished by the U. S. Geological Survey, has resulted in a material saving to the State.

Work on the Kaskaskia, Big Muddy and Embarrass rivers was at once taken up and plans were made for work on the Wabash and Sangamon in 1908. Mr. P. E. Fletcher of Vandalia was appointed

resident engineer of the Kaskaskia project and promptly took the field for the running of primary level lines, being assisted by John Fletcher. The mapping in this area was placed in charge of Mr. E. W. McCrary, assistant engineer, who later, on Mr. Herron's return to Washington, assumed general charge of the work in the State. On the Kaskaskia three sheets, including 160 square miles, were completely surveyed on a scale of 2,000 feet to the inch, with five foot contours. In addition, traverse work and leveling were done preparatory to mapping the remainder of the river.

On the Big Muddy and the Embarass rivers the work was taken up in connection with the regular topographic work in those regions, Messrs. W. J. Lloyd and J. F. McBeth being in charge, respectively. Messrs. J. S. Rohrer, G. L. Gross and James E. Tichenor were employed in the work and approximately thirty-four square miles were surveyed.

On the Little Wabash the small scale topographic maps already in part available were photographed up preparatory to next season's field work. The main work on this river was, however, by agreement done by Mr. L. Hidinger, under charge of C. G. Elliott, chief of Drainage Investigations of the U. S. Department of Agriculture. On the Sangamon the available small scale work was photographed up and prepared for next season's work. The progress of the work is shown in Plate 1.

Further details regarding these surveys are given in later pages. It is believed that they afford a substantial contribution to one of the most serious engineering problems of the State and that they should be carried on until all the river bottoms involved are provided with adequate maps, so that a satisfacory solution of the engineering problems involved in their reclamation may be reached.

## Publications.

*Reports printed.*—Within the year, three bulletins, Nos. 4, 5 and 6, have been issued and at the close another, No. 7, was in press. The complete list of publications so far issued is given below:

Bulletin 1. The geological map of Illinois, by Stuart Weller. Including a folded colored geological map of the State on the scale of 12 miles to the inch, with descriptive text of 26 pages. Gratuitous edition exhausted. Sale price, 45 cents.

Bulletin No. 2. The Petroleum Industry of Southeastern Illinois, by W. S. Blatchley. Preliminary report descriptive of condition up to May 10, 1906; 109 pages. Gratuitous edition exhausted. Sale price, 25 cents.

Bulletin 3. Composition and Character of Illinois Coals, by S. W. Parr; with chapters on the Distribution of the Coal Beds of the State, by A. Bement; and Tests of Illinois Coals under Steam Boilers, by L. P. Breckenridge. A preliminary report of 86 pages. Gratuitous edition exhausted. Sale price, 25 cents.

Bulletin No. 4. Year Book of 1906, by H. Foster Bain, director, and others. Includes papers on the topographic survey, on Illinois fire clays, on limestones for fertilizers, on silica deposits, on coal, and on regions near East St. Louis, Springfield and in southern Calhoun county; 260 pages. Postage, 9 cents.

Bulletin 5. Water Resources of the East St. Louis District, by Isaiah Bowman, assisted by Chester Albert Reeds. Including a discussion of the

topographic, geologic and economic conditions controlling the supply of water for municipal and industrial purposes, with map and numerous well records and analyses. Postage, 6 cents.

Bulletin 6. The Geological Map of Illinois, by Stuart Weller. (Second edition). Including a folded colored geological map of the State on the scale of 12 miles to the inch, with descriptive text of 32 pages. Gratuitous edition exhausted. Sale price, 45 cents.

Bulletin 7. Physical Geography of the Evanston-Waukegan Region, by Wallace W. Atwood and James Walter Goldthwait. Forming the first of the educational bulletins of the survey and designed especially to meet the needs of teachers in the public schools. 102 pages; postage, 6 cents.

Circular No. 1. The Mineral Production of Illinois in 1905. Pamphlet, 14 pages; postage, 2 cents.

Circular No. 2. The Mineral Production of Illinois in 1906. Pamphlet, 16 pages; postage, 2 cents.

Circular No. 3. Statistics of Illinois Oil Production, 1907. Folder, 2 pages; postage, 1 cent.

The distribution of these reports so as to prevent waste, and yet make them most widely available, has been in itself a considerable task. It was thought that the interests of all concerned would be best met if 500 copies of each report be reserved for sale at the cost of printing, the receipts from the sales being turned into the State treasury. This makes it possible for libraries to complete their sets and for persons having real need for any of the volumes to obtain the earlier ones at small cost. The remainder of the edition is distributed by the survey and the Secretary of State to institutions and individuals making application for them or exchanged with other surveys or publishing organizations.

Any of the published reports will be sent upon receipt of the amount noted. Money orders, drafts and checks should be made payable to H. Foster Bain, *Director.*

The topographic maps completed and published are distributed from Washington, the State having made no provision for publishing a local edition. They may be purchased at the rate of 5 cents each or $3.00 a hundred. Drafts or money orders should be sent to the Director, U. S. Geological Survey, Washington, D. C. He is not allowed to receive postage stamps or personal checks in payment. The areas already surveyed and the names of the maps are shown in plate I.

*Reports in Preparation.*—In addition to the reports listed above a considerable number are in an advanced stage of preparation and are expected to be ready for the printer within the current year. These include the following:

Yearbook for 1907; submitted with this report.

Report on paving brick clays of the State by Messrs. C. W. Rolfe, R. C. Purdy, I. O. Baker and A. N. Talbot.

Report on the Mineral Content of the Underground Waters of the State; by Dr. Edward Bartow; with a chapter on the Geological Classification of the Underground Waters of the State by Dr. J. A. Udden.

The Mississippi Valley between Savanna and Davenport, by J. Ernest Carman.

Physical Features of the Desplaines Valley, by James Walter Goldthwait.

Physical Geography of the East St. Louis District, by N. M. Fenneman.

In less advanced condition are educational bulletins on the Springfield, Wheaton and middle Illinois valley regions; a preliminary report on the Portland cement materials of the State; a preliminary report on the coal fields, and areal reports on the Peoria, Springfield, East St.

## Expenditures.

Louis and the New Haven-Thompsonville regions, the latter to be published in coöperation with the U. S. Geological Survey.

The annual appropriation for the survey, including the topographic work, is $25,000. Of the money available July 1, 1906, $10,000 was allotted for coöperative topographic surveys to meet a similar allotment made by the U. S. Geological Survey. In 1907, owing to a reduction in their appropriation, they were only able to meet an allotment of $8,000, which accordingly was made; leaving $17,000 for geology and general expenses for the fiscal year. In addition, there was the special appropriation of $15,000 for the drainage surveys. The statement of expenditures for general purposes is therefore as follows:

| | | |
|---|---|---|
| Balance on hand January 1, 1907 | | $6,327 61 |
| Expended January 1 to June 30, 1907— | | |
| Administration | $1,396 57 | |
| Office | 1,146 72 | |
| Coal investigations | 1,412 92 | |
| Clay investigations | 429 20 | |
| Educational series | 415 03 | |
| Water investigation | 91 00 | |
| General stratigraphy | 401 42 | |
| Mineral statistics | 236 02 | |
| Printing reports | 102 00 | |
| Miscellaneous | 690 43 | |
| | | 6,321 64 |
| Balance July 1, 1907 | | $5 97 |
| Appropriation of 1907-1908 | | $25,000 00 |
| Topographic allotment | $8,000 00 | |
| General Geology—Expended July 1 to December 31, 1908— | | |
| Administration | 1,117 90 | |
| Office expenses | 1,252 65 | |
| Coal surveys | 2,536 62 | |
| Clay surveys | 706 25 | |
| Cement materials studies | 1,429 14 | |
| Oil surveys | 689 31 | |
| Educational series | 146 80 | |
| General stratigraphy | 1,953 17 | |
| Mineral statistics | 50 00 | |
| Special studies | 190 00 | |
| Printing expenses | 721 42 | |
| Miscellaneous expenses | 905 98 | |
| | | 11,699 24 |
| Balance on hand January 1, 1908 | | $5,306 73 |
| Special appropriation for survey and study of overflowed lands | | $15,000 00 |
| Amount expended to January 1, 1908 | $4,515 08 | |
| Balance on hand January 1, 1908 | | 10,484 92 |

The topographic funds allotted by the State have been completely expended. Under miscellaneous expenses are included such items as furniture and instruments, alteration of rooms, etc. The funds reserved for special studies were allotted at the beginning of the year for any special investigation not otherwise provided for which might become of immediate importance. A portion of the fund for 1907 was spent in certain supplementary work needed to complete the paving brick report.

The expense for printing is due to the fact that under the general law the Board of Commissioners of State Contracts, who have charge of printing the reports of the survey, are unable to furnish engravings

and illustrations which are essential to gelogical reports. Certain note books, letter books, etc., needed in the survey work must also be purchased outside. These items, with the postage on reports, constitute in the aggregate a considerable drain on the resources of the survey.

# ABSTRACTS OF REPORTS ISSUED IN 1907.

## Contents.

## Water Resources of the East St. Louis District.*

(By Isaiah Bowman, assisted by Chester Albert Reeds.)

*Introduction, by Isaiah Bowman*—The East St. Louis district, as the term is used in this report, includes the city of East St. Louis and that part of the surrounding territory that lies within what is known locally as the terminal limit, or the yard limits of the Terminal Railroad Association. As thus defined, the district is limited on the west by the Mississippi river and on the east by the towns, Belleville and Edwardsville. Among the larger towns lying within the area may be mentioned Alton, Granite City, Madison, Collinsville, O'Fallon and East Carondelet. The boundaries of the district do not conform to county or town boundaries, but follow an irregular course.

In this district there has been a rapid growth in manufactures in recent years, and a corresponding growth of interest in the problems of water supply. Many physical conditions lead to the embarrassment of the East St. Louis manufacturer. Foundation sites are always poor, the grounds and buildings are often inundated at high water, and the securing of an adequate and cheap supply of water is oftentimes rendered exceedingly difficult. The layman is, therefore, led to inquire why the site is not abandoned and manufacturing plants located nearer the center of the city and homes of the worker. The answer to this query is found in the economic situation. In the organization of any railway system the problem of freight charges is commonly solved by referring the shipments to what are known as basic points. In the early development of the railway system in the St. Louis district, East St. Louis, and not St. Louis, was made the basic point for shipments and has remained the reference point up to the present. In making shipments to St. Louis from eastern points, a certain rate is charged to East St. Louis; and transshipment to St. Louis, from the east, involves the shipper in extra expense. The actual working of the transportation system, as at present organized means that every loaded car crossing either the Eads or the Merchants' bridge into St. Louis pays a toll of $5.00. Every ton of coal burned in St. Louis costs the user 30 cents more than on the east side of the river. The word "toll" as used above is the designation of the citizens of this city; the railroad people call it freight—the ordinary cost of shipment beyond a basic point.

*Topographic Features, by Isaiah Bowman*—The control which topographic features exercise over the disposition of both surface and ground water is often immediate and dominating. In the East St.

*Bulletin 5.

Louis district the influence of topography is emphasized by the sharp topographic contrasts displayed between the eastern and the western sections of the area. The eastern part of the district will be referred to as the upland portion, in contrast to the lowland portion or the flood plain.

That part of the upland included in the East St. Louis district lies so near the lowland bordering the Mississippi that it is much more fully dissected, and therefore uneven, than more central portions of the State. The process of dissection has, however, not been carried to the point of maturity. In the process of valley widening by development of the meanders of the Mississippi many minor tributaries were gradually shortened in an up-stream direction until at last the stream was in some cases betrunked, and the individual headwater tributaries are now almost, if not quite, isolated. In such cases the grades of these headwater sections are steepened to correspond to the lower level enforced by the master stream. This is accomplished by the excavation of large amounts of material near the point where the tributary debouches on the flood plain; such material being in part accumulated in the form of an alluvial fan stretching forward from the bluff. The mouth of the deepened tributary offers a most desirable locus for a dam and reservoir, and if the water shed can be adequately protected from impurities and no legal difficulties are interposed by residents, these localities or similar ones are frequently chosen.

A section of the upland which is of more special interest than any other part lies on the southern margin of the district and includes the area between the upland bluff south of Stolle and the westermost tributary of Hickman's creek. The St. Louis limestone appears here at a higher level than farther south and has been extensively dissolved out by the action of the ground water. The most striking characteristics of this district are the entire absence of trunk drainage at the surface and the extensive development of sink holes, giving a "Karst" topography. Rainfall is concentrated in tiny channels, which converge toward the center of the sink, where the waters escape through cracks and funnels in the limestone below.

*Hydrographic Features, by Chester A. Reeds*—The Wood river drainage system drains the extreme northern portion of the district. It is formed by the confluence of two branches, the East and West Forks, which unite at the western margin of the upland, then flow southward about three miles to the Mississippi river. The two forks have their sources in the southern part of Macoupin county, about sixteen miles above its mouth. The stream has a drainage area in the upland of approximately 117 square miles and in the flood plain of three square miles and has a maximum discharge of about 2,900 cubic feet per second. That part of the channel of Wood river which lies in the floodplain is entirely west of the Big Four railroad, and in freshets its flood waters are here confined. Generally speaking, Wood river may be considered as having no effect on the flood plain. The water in the lower course of the stream is always muddy. Through the first mile after entering the flood plain it flows over a limestone bottom which holds up the grade nearly ten feet higher than that of other

streams having earth bottoms. When the rock bottom is passed, however, the water rapidly falls ten feet and enters the Mississippi river at the level of low water mark at that point.

The Cahokia creek system drains over half the area of the flood plain; all that portion north of the Vandalia railroad and east of the Big Four railroad. The stream has its source in the vicinity of Litchfield, Montgomery county, entering the flood plain about thirty-five miles south of its source. Cahokia creek enters the bottoms with a drainage area behind it of 226 square miles and a discharge of about 5,040 subic feet per second. After entering the flood plain Cahokia creek has a uniform fall of three feet to the mile, or three times that of the Mississippi. Horseshoe lake acts as a storage reservoir for the flood waters of Cahokia creek, and thus protects East St. Louis and the country west of it.

Prairie du Pont creek is formed by the confluence of several smaller streams, which drain about forty-two square miles in the southwestern part of St. Clair county. In addition, Schoeberger and Brouilette creeks, respectively, drain a considerable portion of the upland above French Village and Centerville. The total discharge of these streams, as they debouch upon the flood plain, is 2,350 cubic feet per second. In the Prairie du Pont area the effect of heavy rainfall is much less serious than in the Cahokia district, since (1) there is much less volume of water to deal with, (2) numerous lakes act as reservoirs and thus retard the flow and (3) Prairie du Pont creek seldom overflows its banks.

At low water mark the Mississippi river receives the drainage of Wood river, Cahokia and Prairie du Pont creeks. The mouth of Wood river it at low water level, while those of Cahokia and Prairie du Pont creeks are respectively seven feet higher. When the water of the Mississippi river rises thirty feet above low water mark the flood plain is subject to overflow. When the river rises to thirty-five feet it is considered dangerous, for there is approximately only 10 per cent of the land of the flood plain above this elevation. At the present time the lowlands are protected from overflow by strong levees near the river bank. During the last sixty years the stage of the Mississippi river has been above elevation 30 on sixteen occasions and during the same period has been at or above elevation 35 in seven instances.

*Geologic Features, by Chester A. Reeds*—Although the only rocks which outcrop along the east bluff of the Mississippi are thick beds of the Mississippian and of the Pennsylvanian (coal measures) series, it is necessary to consider some of the lower formations, since in drilling deep wells older rocks are encountered. The data concerning these older rocks, however, are meagre and come from the logs of the few wells reaching down 2,000 to 3,000 feet and from exposures outside the district.

The lowest formation which has been encountered within the district is the St. Peters sandstone, at the bottom of a 3,069 foot well at the Postel Milling Company's plant, Mascoutah, Illinois. The water in the Mascoutah well which flows at the surface is brackish and unsuitable for domestic use. The Trenton limestone does not outcrop within

the district, but reaches under the Mississippi river and appears in the rugged hills along the west bank from Kimmswick southward. The drill has shown that parts of it in western Illinois, buried deeply beneath later formations, will yield strong artesian wells. The Richmond does not outcrop in the district, but is found about twenty to twenty-five miles south of St. Louis, on the west bank of the Mississippi river.

Only the two upper formations of the Meremec group of the Mississippian series are exposed within the district. The rocks of the Osage and Kinderhook groups are exposed to the north and west along the Mississippi river, and in sinking wells are encountered within the area. The Chester group does not occur within the district. In the few wells reaching the Kinderhook rocks an abundance of water is usually found, but it is brackish and unsuitable for domestic use. Altough the Burlington and Keokuk are wide spread and form a noticeable part of the geological column, they are poor water bearers. The Meramec has been sub-divided by Ulrich into the Warsaw, Spergen Hill and St. Louis limestone. The Warsaw and Spergen Hill formations are not as good water bearers as the St. Louis. In the vicinity of Belleville and Mascoutah the upper part of the St. Louis limestone is the first horizon in which salt water occurs.

The Pennsylvanian or coal measures formation occurs immediately beneath the mantle of drift and extends over all the district except the western bottoms and the Karsted region. The formation is composed of alternating beds of sandstone, shale and limestone, in addition to a few grits and conglomerates and thick beds of coal. In conforming to the western slope of the eastern interior coal field these strata dip gently to the west ward. At the base of the coal measures a sandstone conglomerate is persistent throughout. This is the chief source of supply of the artesian wells at Belleville.

The entire surface of the Illinoian drift sheet appears to have received a capping of loess-like silt at about the time of the Iowan ice invasion. In much of southern Illinois the thickness is only from three to five feet, and the average depths in districts east of the Illinois and Mississippi is probably less than ten feet. On the borders of these streams its thickness is frequently from thirty to fifty feet. At the immediate edge of the Mississippi valley above East St. Louis there is a deposit from thirty to fifty feet in depth, but within ten miles back from the bluff the thickness decreases to ten feet or less. Below East St. Louis the loess caps the bluff to a depth of from thirty to fifty feet or more. The till and loess are the source of the shallow well supply of water.

The alluvial deposits within the district are confined to the flood-plain of the Mississippi river. In this plain the sediments increase in thickness in going from west to east. At Granite City they are 113 feet thick; at Monks Mound, 140 feet; near Peters, 150 feet. Throughout the flood plain the sediments are arranged in no definite order, but in sinking wells the larger materials, such as gravel and pebbles, are usually found near the bottom, while the smaller sediments, such as fine sand, clay, gumbo, etc., occur near the surface.

*Surface Sources of Water Supply, by Isaiah Bowman*—Cisterns for supplying water are in use in various places in the East St. Louis district. It is recommended that the cisterns be cleaned oftener, especially in summer, when a large amount of germ-laden dust is carried aloft and deposited on house tops. With the help of a candle the cistern wall and bottom should be examined thoroughly at each cleaning to detect the presence of any cracks which may have formed and which may allow the entrance of and pollution by ground water or by karst water.

No springs of significance occur within the East St. Louis district except Falling spring. The principal source of stream water within the East St. Louis district is the Mississippi. The gravest general problems, and most serious mechanical difficulties in the whole East St. Louis district which up to the present time have been met and overcome are those involved in the acquisition, cleansing and delivery of the water of the Mississippi. The various difficulties and problems which arise may be understood from the experiences of the City Water Company of East St. Louis and Granite City.

The pumping station for the Granite City division of the company is located on Cabaret island. The district is one of filling, and this embarrasses the company in the use of the suction main. Whenever the sand accumulates in such amounts as to close the suction, a diver cleans it away. The sand has also been removed by anchoring a scow over the end of the main. The deflection which the shape of the bow and bottom of the scow gives to the current concentrates more powerful threads of the current on the bottom than under natural conditions and bottom scour results. The East St. Louis division of the City Water Company has its pumping station just within the main levee at the northern end of the Terminal Association's switch yard in East St. Louis. The mains pass through a check built into the bank and extend for 250 feet into the river, from ten to twenty feet below the surface of the water. They are supported by log chains strung between piles and terminate in screens or strainers. The strainers are constantly being clogged by river-borne detritus. The same difficulties with bank sand and mud are here experienced as in the case of the pumping station on Cabaret Island. It is no light undertaking to render Mississippi river water fit for use. It will be seen that unless a company is using a very much greater amount of water than any in this district, it cannot expect to maintain a filtering plant with any hope of reasonable returns. The City Water Company has undertaken and is successfully carrying out the plan of serving its clients with clear, pure and palatable water. Its engineers and chemists have mastered many difficulties and are entitled to great credit.

The principal tributary streams of the East St. Louis district are the Wood river and Cahokia and Prairie du Pont creeks, as sources of potable water. One of the most important considerations is that of possible pollution. None of the tributary streams in this district are bordered by towns or villages of any consequence in this connection. The greatest difficulty in using the water of the smaller streams in this district lies in the irregularity of the volume and the rapid change

in quality which takes place during and after sudden downpours of rain. Any filter plant must be as elaborate as to detail as if the streams were constantly turbid.

There are a few large lakes in the East St. Louis district of value as a source of water supply. On the whole, lake water is not a satisfactory source of supply in this district. Stream or well water will, perhaps, always be used in preference in limited amounts in favorable localities, where the lake water offers a desirable resource in fire protection. In a few cases—for example Glen Carbon and Belleville—the water of streams is impounded in a reservoir. Except in the case of Belleville the reservoir water is nowhere used for drinking purposes, and even in this case to a limited extent only at infrequent intervals. The difficulty of securing a protected watershed in the well settled part of the State, included in the East St. Louis district, will always mean a very limited use of impounded water. The use of ground water recovered in shollow wells will be likely to supersede even such uses of stored water as now exist.

*Underground Sources of Water Supply, by Isaiah Bowman*—The natural position of the Mississippi flood plain with respect to the river which formed it and the importance of that river in commerce would tend under any circumstances to make its population dense. Above New Orleans no city, with the exception of Greenville, derives its supply from the flood-plain waters. There are several conflicting theories among local students regarding the source of the ground water and its direction of flow. Some have asserted that the source of the ground water is the Mississippi river; that the river is constantly losing volume by seepage through the porous sand and gravels which here form its eastern bank. Others maintain that the source is the flood water which, when the river is highest, overflows the flood-plain and stands upon it for some time, undoubtedly sinking into the ground to some extent. Still a third class contend that the rainwater which sinks into the upland seeps westward, and with the upland streams which lose their waters on the inner margin of the flood-plain constantly replenish the flood-plain waters to the extent of causing them to move westward to the river. We may dispose of the first contention by pointing out that during most of the year the ground water of the flood-plain stands at a higher level than the surface of the Mississippi. This general contention does not hold true, however, during a period of high water when the river is rising against the outer side of the restraining levees, and stands higher than the surface of the ground water. Although this condition is, relatively speaking, exceptional and unimportant, it must be considered in appreciating the general result. It is the popular conception that at such periods of high water the "backflow" as it is commonly called or the seepage from river to flood-plain fills these deposits to the degree to which they were depleted during the preceding year. That such a rate of seepage is impossible is shown by the results obtained by Professor Slichter and noted in "The Motions of Underground Waters." As far as a continuous supply is concerned, lateral seepage through or below levees is not an important factor. If the flood-plain is actually covered with water

during the flood season, the rate of increase in the amount of ground water is of course much greater than in the case just discussed. The period which this effect covers and the relative infrequency of complete submergence of the flood-plain would argue that even the flooding of wide areas is not to be regarded as of importance.

The key to the normal condition of the ground water is the rainfall upon the flood-plain itself and the supply from the upland. The mean annual rainfall is about 38 inches per year. The surface of the flood-plain is so flat that the rate of run-off is exceedingly low. A large part of the rainfall sinks into the ground, perhaps in excess of 50 per cent; which means roughly, half a million gallons yearly per acre, or 300,-000,000 gallons yearly per square mile, or, on the average, 1,000,000 gallons per square mile daily. The normal condition of the ground water in the flood-plain is maintained by rainfall and tributary upland drainage which produce a general movement of the water toward the Mississippi, this general movement being modified here and there by slight topographic variations. The flood water contribution is insignificant except in cases of actual overflow, and even in the latter case the effect is temporary.

The wells in the flood-plain deposits vary in depth from 10 to 150 feet. Since a greater supply can be had by sinking the wells to a depth of 40 feet than 10 feet, most individuals do this, the additional expense not being great. Where factories have put down wells they have usually gone deeper, since they need a larger supply that for household use. Although the waters of the Mississippi flood-plain may be recovered without great difficulty, the water when so recovered is undesirable for boiler purposes on account of the scale which forms from its use. This condition can be remedied by chemical treatment and through filteration, but the erection of a plant for this purpose is expensive. To purchase from the Water Company would seem to be the most advisable plan for those located near the larger tributaries of the Mississippi.

The southwestern part of the East St. Louis district which lies south of Stolle and between the upland bluff and Hickman's creek, must depend upon Karst water. The Karst waters of a limestone region are less safe, less constantly clear, and less available than are the waters of a region of normal sub-surface drainage. Even the ground water is less available than under ordinary conditions, and less safe on account of the quick descent of surface drainage which elsewhere seeps slowly down through porous materials and is, thereby at least partly filtered of its impurities.

*Artesian Conditions, by Isaiah Bowman*—The deeper horizons are to a large extent, independent of surface drainage, since the direction of flow is determined by geologic rather than topographic features. The rocks of this area are composed of sandstone, shales and limestones, and that they dip from the west to the east, producing artesian conditions. The flowing wells within the district tap the lower geological formations since it is only here that the water is found under sufficient head to rise to the surface. The flowing wells are located as follows: Mascoutah, 3,069 feet deep; Granite City, 2,590 feet; Peters,

1,506 feet; Edgemont, 782 feet; Alton, 1,400 feet; Monks Mound, 1,552 and 2,100 feet. Unfortunately, the water in the deep wells below 515 feet on the upland, and 370-420 feet on the flood-plain, are brackish and unfit for factory, city or private use. The water found in the St. Peter's sandstone is brackish in all cases when reached in this area, consequently in future drilling for deep city or factory supply, it will be unprofitable to go below the first salt water horizon.

*City and Village Water Supplies and Systems, by Chester A. Reeds*— At Belleville the city water is furnished in part from artesian wells drilled in the valley of Richland creek and in part by impounded water from Richland creek and its tributaries. The depth of these deep wells varies from 400 to 700 feet. The water-bearing horizon dips to the east in conforming to the gentle slope of the western rim of the eastern interior coal field, and is a sandstone found at the base of the coal measures. The water obtained from this sandstone in Belleville is of a fine quality. The amount of wells is decreasing. Edwardsville is supplied by a private company. The five wells and pumping station are located at Poag. Collinsville, like Edwardsville, is situated on high ground overlooking the "American bottoms." Following the lead of Edwardsville, the water company of Collinsville sunk wells in 1901, in the "American bottoms," near the Madison-St. Clair county line, about one-fourth of a mile from the bluffs. At Caseyville there is no water or sewer system. Shallow wells from 25 to 40 feet deep afford an abundance of water.

Alton gets its water supply from the Mississippi river, through a system similar to the ones in use at East St. Louis and Granite City. The intake pipe rests on a rock foundation 3½ feet below low water mark. By a nice arrangement of dikes in the Mississippi river, above the plant, a strong current is thrown past the station which keeps the intake pipe free from sediment. The water is pumped from the Mississippi river into a well 20 feet in diameter, through a 24-inch pipe 100 feet long. From the well the river water is raised into the settling basin where it is treated with solutions of lime and sulphate of iron, which reacting with each other and with substances in solution form a precipitate which carries down the matter held in suspension. The amount used varies with the condition of the water. On May 31, 1906, 1,102 pounds of lime and 334 pounds of sulphate of iron were used to precipitate the suspended matter carried in 2,500,000 gallons of river water. The lime and sulphate of iron run constantly into the settling basin through iron pipes leading off from separate dissolving vats located above, and at the east end of the basin.

From the settling basin the water runs over into the filtering room, where six of the New York gravity type of filters are. These filters are each 15 feet in diameter, 8 feet deep, and are filled with sand to a depth of 5 feet. The sand is taken from the river, but is cleaned before being put to use in the filter. When the water has percolated through the filters, it is raised 240 feet into the reservoir situated on the hill northwest of the city. The plant was completed nine years ago at a cost of $220,000.

The East Alton water supply is obtained from private wells scattered over the village. In most cases these are driven to a depth

from 18 to 25 feet through the sandy loam and quicksand which have been deposited near the junction of the east and west works of Wood river. Glen Carbon is dependent upon shallow wells located on the hills as well as in the valley of Judy's branch. The water supply of East Carondelet is obtained from shallow wells driven into the alluvial deposits to a depth of from 25 to 30 feet. The water supply of O'Fallon is obtained from shallow wells in the glacial drift. At Mitchell the wells are on a sand ridge which runs south from Wood river and east along the north side of Long lake. The Nameoki water supply is derived from wells driven into the flood-plain deposits to a depth of from 25 to 60 feet. The water is not of the best quality. Granite City, East St. Louis, Madison and Venice are supplied by the City Water Company of East St. Louis and Granite City, which maintains two pumping stations, one at East St. Louis and one at Granite City.

*Analyses and Well Sections, by Chester A. Reeds*—Numerous sanitary and mineral analyses of the waters of the district are given. The larger portion were made in the laboratory of the State Water Survey, the samples being in part collected by officers of the Geological Survey and in part sent in by private citizens. An inspection of these results show that wells over 500 feet deep contain an amount of mineral matter that would prohibit their use for boiler and manufacturing purposes. One exception to be noted, that of a 782-foot drilled well at Edgemont, which contains practically no incrustants, and while containing a considerable quantity of salts of the alkalies could be used in boilers. Wells from 300 to 500 feet deep contain a considerable residue on evaporation, consisting for the most part of salts of the alkalies, but containing also considerable quantities of calcium and magnesium. The most satisfactory water is obtained from the Mississippi river. The water obtained from many of the driven wells, especially those in the American Bottoms at Poag, is of good quality.

Of the 51 waters analyzed, 14 would be condemned for excessive residue; 19 would be benefited by treatment with soda ash and passing them through a feed water heater, or by treatment with soda ash and lime and allowing the sediment to settle before the water is added to the boilers; 15 would be benefited by treatment with lime alone, and allowing the sediment to settle; and three are sufficient purity to give very satisfactory water without treatment.

*Summary of Conclusion, by Isaiah Bowman*—(1) In those sections of the district where limestone lies above the surface of the ground water and is extensively dissolved out by percolating waters, the available water is karst water. Its recovery is much more difficult than is the recovery of the ground water below it, which it feeds. In this district underground water occurs in the manner in which ground water is popularly but erroneously supposed to occur—that is to say, in definite underground channels. By reason of the quick descent of rain water to these underground passages karst water is often dangerous for drinking purposes, and the population is driven to the use of rain water conserved in kitchens.

(2) The supply of water from streams is not used to the fullest extent today because of the ease with which ground water may be

obtained. The Mississippi river is drawn on for city supply in East St. Louis and a few adjacent towns. The water is extremely roily when first drawn, but by the process of filtering, aerating, sedimentation, baffling and by chemical treatment, it is made clean and pure and wholesome. It scales boilers to some extent, but not so much as the ground water, whose use is supersedes. Use can likewise be made of tributaries of the Mississippi.

(3) A number of ox-bow lakes and artificial reservoirs are utilized, but the extent to which this is done is and always will be quite limited. The lakes are roily in spite of some degree of natural sedimentation, and the rank growth of vegetation and the large amount of city wastes dumped into them would lead to deleterious effects were the water used for drinking purposes. The reservoirs are favorable means for securing a public supply, except to the extent to which the watershed is contaminated by wastes. The growth of vegetation on their bottoms and shores may easily be prevented by deepening and graveling the bottom and paving the sides.

(4) For drinking and other domestic purposes the ground water of the flood plain must always constitute the chief source of supply to the flood plain population. By virtue of the fact that fine sands overlie the coarser sand and gravel from which the water is derived, the purity of these waters under ordinary conditions, must always be assured. Not that the fine sands prevent the downward movement of the rain water into the gravels and coarse sands, but that they enforce a movement sufficiently slow to insure pretty thorough filtration. The gravel and coarse sand are not more thoroughly saturated with water than the fine sand above them, but their water is more available and wells are not regarded as successful which do not reach lenses of coarser material. For boiler purposes the flood plain water is not desirable in its natural state, being too heavily charged with calcium and magnesium carbonates. The use of purifying compounds is required with it. Several companies are considering the erection of purifying plants which will enable the use of this water, but at present city water is used in the boilers.

(5) The greater part of the upland will always be supplied with water from shallow wells in favorable localities in the loess and drift, the bottom of the well lying a few feet below the level of the water table. No special features of water quality or means of acquisition need be summarized here as the problem is wholly one of the simple dug or driven well of the ordinary type.

(6) The deeper waters are all highly mineralized and occur under much greater head than the shallow supplies. They are not valuable except for their medicinal properties, either real or supposed, and can never enter directly into the problem of water supply in a serious way except by possible pollution of sweet surface waters. Occurring with such a great head and with strong mineral substances in solution, they must sooner or later, with the decay of the casings enter upper horizons to the exclusion of desirable waters. These upper waters are even at present too hard for boiler use, and will be totally unfit for such use if re-enforced by the water from deep sources. It would be

calamitous, indeed, should such a displacement ever occur, and it can not be too strongly urged that the State adopt measures which will give the upper horizons adequate protection.

# The Geological Map of Illinois.*

(By Stuart Weller.)

*Introduction*—The position of the natural economic products which exist within the crust of the earth in any region, is determined either by the physical conditions present at the time of formation of the rocks in which they are contained, or by reason of subsequent dynamic changes. It is the task of the geologist to investigate the ancient history of the earth, to observe the peculiar characters of the rock strata, and to determine, if possible, the conditions under which they have been formed; and also to investigate the changes through which the strata have passed since their deposition. All these observations are recorded graphically upon the geological maps which the geologist constructs. While in general the rocks of the State are flat-lying or have imperceptible dips, they are not absolutely horizontal. Taken as a whole the eastern interior coal field, which occupies most of the State, is a great shallow, synclinal basin with dips towards the center from all sides. These dips can be measured only in feet per mile. They are, however, a few lines along which the dips are reversed, so that there are certain poorly defined anticlinal areas. These have not yet been carefully worked out, though the more important ones are noted.

*Geological Formations*—The Potsdam sandstone is nowhere exposed at the surface in Illinois, but it has been penetrated in several deep wells in the northern portion of the State, the greatest thickness observed in his manner being about 1,000 feet, but nowhere has the bottom of the formation been reached. This sandstone doubtless continues southward underlying the entire State of Illinois. Because of its large lateral extent and its porous character, it constitutes a reservoir from which an abundant supply of water can be obtained.

The Lower Magnesian limestone comprises the most ancient beds exposed in the State. The largest exposed area is along the Illinois river in the neighborhood of Utica, in LaSalle county. Other small areas are known along the Little Vermilion river and Tomahawk creek north of LaSalle. Outside of LaSalle county the formation is known only in western Ogle county where it outcrops for several hundred yards along the south bank of Elk Horn creek, and in Calhoun county where a few feet are exposed at low water beneath the St. Peter sanstone at Cap au Gres bluff. Like the subjacent sandstone it doubtless underlies the entire area of the State.

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Outcrops of the St. Peter sandstone are confined almost entirely to the northern portions of the State, where it is usually a soft, light colored, friable sandstone. Two principal areas are recognized; the first along the Illinois river from east of LaSalle to the mouth of Fox river, and up the valley of that stream for some distance, with a small detached area in the edge of Kendall county, the valleys of the Vermilion and the Little Vermilion rivers which empty into the Illinois at LaSalle; the second area lies in the valley of the Rock river from a short distance above Dixon to beyond Oregon, and up the valleys of the chief tributaries. Besides these areas this formation is the surface rock in a small area in the western part of Ogle county. There is only one recognized exposure of the formation in southern Illinois, and that a small one in Calhoun county on the bank of the Mississippi river where this formation forms the southern extremity of the Cap au Gres bluff. The maximum thickness of this formation in the State, as shown in deep well records, is 275 feet. Like the two preceding formations the St. Peter sandstone has a much greater distribution than is indicated by its limited surface exposures. The formation is eminently porous and is freely penetrated by the underground waters, and is of great economic importance as a reservoir from which an abundance of water may be secured by means of deep wells.

The Trenton-Galena formation as now mapped includes all the calcareous dolomitic beds between the St. Peter sandstone below and the usually shaly or arenaceous Cincinnati beds above. In the northern portion of the State these strata have a thickness of from 300 to 400 feet, as shown in deep well records in the central portion of the State in Calhoun and Jersey counties, about 250 feet have been recognized; in southern Illinois the entire thickness of the sediments is nowhere exposed, less than 100 feet of the uppermost beds being known. In the northwestern portion of the State only the upper or Galena dolomite member is well exposed. In the west central portion of the State, three formations are recognized. These are the Joachim dolomite below, followed by the Plattin limestone, with the Kimmswick limestone at the summit. In the southern portion of the State a small exposure of Kimmswick limestone underlain by the Plattin occurs in the Mississippi river bluffs at Valmeyer, Monroe county, and a somewhat larger area extends north and south of Thebes in Alexander county.

The beds of Cincinnati age vary greatly in lithologic character in the different parts of the State and seem to be limited to the uppermost or Richmond division of the formation as it is more completely developed in the region of the formation lying east of the Cincinnati arch. In the northwestern part of the State the formation is represented by the Maquoketa formation which is, in the main, a bed of blue or green clay shale with occasional bands of dolomite and limestone. In this region it attains a thickness of from 140 to 175 feet. In Calhoun county the formation is a green shale which becomes somewhat dolomitic towards the base, but is reduced in thicness to about 75 feet. In Monroe county the formation is similar in character and in thickness to that in Calhoun county, but is under-

lain by a limestone bed one or two feet in thickness which bears a typical Richmond fauna. In the northeastern portion of the State the Cincinnati beds are well shown in the banks of the Kankakee river above Wilmington, where they are more calcareous than along the Mississippi, and contain an abundant fauna of the Richmond type. In the southern part of the State, at Thebes, in Alexander county, the Cincinnatian is represented by two divisions, a lower sandstone member, the Thebes sandstone, about 75 feet in thickness, and an upper member, the Cape Girardeau limestone, about 40 feet in thickness.

The rocks of Silurian age in Illinois have always been referred to in the literature of the State as the "Niagara limestone." This formation, however, probably represents a much longer time interval. In northeastern Illinois the Niagaran limestone occupies a great area extending from central Iroquois county to the Wisconsin state line; in this region the beds attain a thickness of from 300 to 388 feet, and consist, for the most part, of more or less massive dolomites of a bluish or buff color, such as are exhibited along the Chicago drainage canal and along the Desplaines river valley to Joliet and beyond. In the northwestern part of the State the Silurian occupies considerable areas in the valley of the Mississippi river and its tributaries, where the beds are similar to those further east in their dolomitic character, and are usually of a buff color. In Jersey and Calhoun counties these rocks again come to the surface in the valleys of the Mississippi and Illinois rivers, north of the Cap au Gres fault, with a thickness of from 50 to 120 feet; here again the beds are dolomitic, usually massive and of a buff color, and are especially well exposed at and near Grafton. In the southern portion of the State, in Jackson, Union and Alexander counties, there is a considerable area indicated as Silurian on the map which needs further careful investigation.

Strata of Devonian age form the surface rock at three widely separated regions in the State. The first of these is in Rock Island county, where the rocks have a maximum thickness of about 150 feet, although only about 75 feet are exposed, the total depth of the formation being known from deep well records. These strata are of middle and upper Devonian age, are mostly limestones. The second Devonian area is in Calhoun and Jersey counties, where scarcely more than ten feet of limestone of this age are present. The third area is in the southern portion of the State, in Jackson, Union and Alexander counties; the beds are chiefly limestones and sandstones, and they contain fossil faunas of middle Devonian age. In the southeastern portion of the State, in Hardin county, a small area of Devonian black shale is known, which has been recently mapped in connection with the work of the United States Geological Survey in that portion of the State. Unlike the preceding formations, the Devonian rocks do not extend continuously throughout the State beneath the younger formations.

The area colored as Mississipian on the accompanying map, extends nearly the entire distance from Mercer to Jackson counties along the Mississippi river, and across the southern portion of the State from Union to Hardin counties. This unit is a very complex one, and in any

future mapping five or more distinct divisions must necessarily be recognized and mapped. The Kinderhook beds comprise various more or less local formations, which may be either limestones, sandstones or shales. The Kinderhook as a group may be recognized from as far north as Burlington, Iowa, to Union county at the south, but none of the component, local formations have any such wide distribution. The formation as a whole varies in thickness from 25 feet to 200 feet.

The Burlington limestone is clearly differentiated as far south as Union county, although it is not continuously exposed through that entire distance. It is usually a highly crystalline, nearly white, crinoidal limestone, with a maximum thickness of about 200 feet, but often contains a considerable amout of chert.

The Keokuk-Warsaw limestone and shale in its typical expression differs from the subjacent Burlington limestone, in its usually darker color, often having a bluish or grayish color, and in the shaly partings which frequently separate the thicker ledges of limestone, sometimes developing into shale beds several feet in thickness. In the Keokuk proper at Warsaw, there is a conspicuous geode bed which may be recognized as far south as Jersey county. The total thickness of the Keokuk proper is about 125 feet. The typical Warsaw beds, about 40 feet in thickness, lie above the geode horizon. The strata are variable in character and comprise beds of dolomite, limestone and shale, but the sedimentation from the Keokuk to the Warsaw is apparently continuous.

The Salem limestone is one of the best defined in the whole Mississippian series in Illinois. It is discussed in detail elsewhere in this volume.

The St. Louis limestone is characterized by the exceedingly variable character of its beds. It is for the most part a limestone of a blue or gray color, being distinctly darker, as a usual thing, than the subjacent Salem limestone. The strata are thick or thin beded, they may be hard, dense and fine grained limestone, or they may be more or less crystalline; shaly limestone and even beds of shale are sometimes present, and some beds in some portions of the State, are more or less brecciated or conglomeratic. A notable characteristic of the formation is the presence of fine grained, dense, limestone beds having a conchoidal fracture and almost the texture of lithographic stone. Occasionally beds of arenaceous limestone are met with. The amount of chert contained in the formation is exceedingly variable. The thickness of the formation is greatest to the south where it reaches 250 feet or more. It thins to the north and is only about 10 feet thick at Warsaw, in Hancock county. The Ste. Genevieve limestone closely resembles the St. Louis. In it, however, oolitic beds which are absent in the St. Louis appear, and it is, perhaps, less cherty than the St. Louis. The main distinction is a faunal one, there being a recurrence of the types of life which were abundant in the Salem, but absent from the St. Louis.

The line dividing the Cypress from the subjacent beds separates the lower Mississippian limestone with a total thickness of 1,000 feet or more, from the upper Mississippian beds which are dominantly sandstones. This upper arenaceous series constitutes the "Chester Group" of the literature, the Cypress sandstone being the so-called

"Lower member of the Chester." The formation is quite uniform in character, a moderately fine grained, yellowish-brown sandstone, rather heavy bedded in its lower portion, becoming more thinly bedded above. Its thickness varies from 80 feet or less to 150 feet or more. The lowest member of the Chester group above the Cypress sandstone, is a limestone and shale formation attaining a maximum thickness of approximately 250 feet at and above Chester. In its lower portion it includes considerable beds of calcareous and clay shales, a bed of variegated red and blue shale being commonly present near the base. In the upper part of this member is a great limestone ledge about 100 feet in thickness, with occasional thin shaly partings, which furnishes the quarry rock at the Southern Illinois penitentiary, at Menard. The second member of the group is a sandstone or shale, the shale being most conspicuous in the more northern part of the area, while to the south it is almost wholly a sandstone similar to the Cypress in character, but usually thinner bedded and not infrequently more or less of an arenaceous shale. This division attains a thickness of about 80 feet. The third member is again a limestone which is apparently more impure than most of the beds of the lower division. It is much less fossiliferous than the lower division and the fossils are such as to give it definite faunal characters which can be recognized over wide areas. Its thickness near Chester is about 60 feet. The fourth member is again a sandstone similar to the earlier sandstone beds, and attains a thickness of 65 feet. The fifth member is a limestone similar to limestone No. 2, in lithologic characters, and is usually almost or quite unfossiliferous. Its thickness is about 35 feet. Following the third limestone is another great sandstone member 100 feet or more in thickness, which is finely exposed back of the village of Rockwood in Randolph county.

No geologic formation in Illinois contains greater economic resources than the Pennslyvanian or coal measures. Here are to be found the enormous coal resources which exceed all other mineral products of the State combined, besides great deposits of clay, usually in the form of shales, and less important beds of limestone and sandstone. The observations already made by the members of the survey upon the Pennslyvanian strata, seem to indicate that the formation of coal began first in the southern portion of the State, so that the so-called oldest or No. 1 coal in that section is older, perhaps very much older than the so-called No. 1 coal in the northern part of the area. Some of the higher beds, however, seem to be more widespread in their distribution, and may perhaps extend over a large portion of the coal fields within the State. In the southern part of the State the basal formation of the Pennsylvania is a sandstone which sometimes resembles the subjacent upper sandstone member of the Chester group, but it is usually a more heavily bedded formation, and is more or less conglomeratic, the included pebbles being of rather small size and of a white quartz material. This formation is the "Mill-Stone Grit" of the older reports, and includes the Mansfield sandstone of the Indiana geologists. Its thickness is 100 to 500 feet. In the central and northern portion of the State the basal sandstone of

the Pennsylvania is not conglomeratic, and is probably much younger than the Mansfield sandstone of the south. The Pennsylvania beds everywhere rest unconformably upon the subjacent formations. One of the important horizons to be studied and accurately mapped in connection with the investigations of the Pennslyvanian by the survey, is a limestone known locally as the "Carlinville" or "Shoal Creek," discussed elsewhere in this volume.

No Permian rocks have been indicated upon the accompanying map, although undoubted vertebrate fossils of Permian age have been known from Vermilion county for many years. Recent investigation of the locality has shown that the "bone bed" so far as it is known, occurs only in strata which have been extensively displaced by land slides.

A map covering the extreme southern portion of the State has been published by Glenn,* in which considerable areas in Pulaski and Massac counties, and a small strip in Pope county, are colored as Cretaceous, and the beds indicated are correlated with the Ripley formation of Mississippi. Heretofore all these beds so indicated within the State of Illinois, have been considered as Tertiary. The beds are all more or less unconsolidated sands and clays of non-marine origin, and according to Glenn they may be traced continuously from southern Illinois across Kentucky and Tennessee into the typical marine Ripley beds of northern Mississippi. Near Caledonia landing and extending some distance north toward Grand Chain are certain clays, green sands and lignitic material believed by Glenn to represent the Porters Creek or Flatwoods and the Lagrange or Lignitic formations of the south. To the west these pass quickly under the alluvial deposits or the pebbles, and unconsolidated gravels of similar age which have been correlated with the Lafayette; a widespread formation of Pliocene age in the southern states. The Lafayette occurs more or less continuously over the embayment area in Alexander, Pulaski, Massac and Pope counties, occupying the higher ground. North of the more or less continuous area of this formation, there is present upon the summits of some of the highest hills in Union county, and eastward in Gallatin county, a capping of ferruginous conglomerate similar to that further south, which marks a further extension of the same formation. Still further north in southern Calhoun county the Lafayette gravels occur on top of the divide between the Mississippi and Illinois rivers, resting unconformably upon the Paleozoic rocks, and buried beneath the loess.

Throughout the greater portion of the State the surface is more or less deeply covered with glacial deposits of Pleistocene age, which add greatly to the difficulty of interpreting the stratigraphy of the older underlying rocks. In the northwest portion of the State is a driftless area comprising the greater portion of JoDaviess county, with portions of Stephenson and Carroll counties. Another small driftless area occurs in southern Calhoun county, and in southern Illinois the drift does not extend south of the conspicuous ridge which crosses the State from near Grand Tower to a point north of

*U. S. Geol. Surv., Water Sup. and Irr. Pap., No. 164, pl. 1.

Elizabethtown. These Pleistocene deposits are variable in their lithologic characters, consisting of unstratified glacial till, stratified sand and gravel deposits, loess and alluvium.

The presence of igneous rocks in Illinois has been recognized only recently, and so far as known they do not occur outside of the southeastern portion of the State. The occurrence of these rocks is in the form of dikes which have been intruded into the Mississipian and Pennsylvanian formations. They fall into two groups, mica-peridotites and lamprophyres. DeWolf has observed, in connection with his work on the coals, the presence of similar intrusives at one or two points in Saline county, where they penetrate the Pennsylvanian formations.

# Physical Geography of the Evanston-Waukegan Region.*

(BY WALLACE W. ATWOOD AND JAMES W. GOLDTHWAIT.)

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*General Geographic Features, by W. W. Atwood*—The area covered by this report lies north of Chicago and extends to the Illinois-Wisconsin line. Its eastern boundry is the lake shore and its western the Desplaines river. The larger part of the area consists of rolling uplands more than sixty feet above the level of the lake. The modern lake cliff extends from the southern margin of Wisconsin southward a little beyond Evanston and varies up to eighty feet, being at places almost vertical. At its base is a modern beach. In the southeast and northwest corners of the area is an old lake plain associated with which are ancient beaches. The drainage of the western portion of the area joins the Desplains river. The central portion is drained by the north branch of the Chicago river while the eastern border is tributary to the lake.

*The Geological Formations, by W. W. Atwood*—All of the rock material within the Evanston-Waukegan region is glacial drift composed of clay, sand, gravel and boulders. Portions of it are stratified and may be referred to as modified drift. Nowhere does the bed rock appear at the surface. The great bulk of the material is unstratified and is known as "till." The clay matrix is highly calcareous and was derived by grinding and crushing from the limestone of the region. Of the stones of the drift, probably ninety per cent are from the underlying Niagara limestone, while the remaining ten per cent are of sandstones, shales and crystalline rock foreign to Illinois. Some of the latter must have been transported at least 500 miles. The general formation of an ice sheet, and the extent and character of the North American ice sheet, together with the work of the glacier ice in erosion and in deposition, are considered in detail, as well as the effect on the topography of the direction of movement of the glaciers.

Glacial deposits such as occur in this region are especially characterized by lithological and physical heterogeneity and by certain peculiar shapes of the pebbles and markings on the latter. In the broadest sense of the term, all deposits made by glacial ice are moraines. Those made beneath the ice and back from its edge, constitute the ground moraine and are distinguished from the marginal accumulations, which are known as terminal moraines. The ground moraine underlies the

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entire upland of this area. It consists of boulder clay composed of more or less comminuted materials derived from the land across which the ice passed. The topography of the drift covered region is marked by swells and depressions, standing in no orderly relationship. It is well shown just west of the Chicago & Northwestern Railroad between Glencoe and Waukegan. Certain portions of the drift have been worked over and redeposited by water, forming stratified drift. A section of this material may be seen at Winthrop Harbor along the main North-South road covered by a layer of bouder clay and later beach sands.

*The Present Shore Line, by J. W. Goldthwait*—The lake forms peculiar short lines, depending for their existence upon those movements of the waters which are initiated by the winds. If there were no winds, such a lake as Lake Michigan would be practically without currents and waves, and its shores would be without strength and character. Shore forms are changing, living objects in so far as solar energy is expended upon them through waves and currents. The principal agencies working upon the shore line are waves, the undertow, and the shore current. When a lake is first formed in an enclosed basin, or when a considerable change in level brings a lake into a new position against the land, waves and currents find a coast which is not adjusted to their erosive and constructive activity. Whatever the nature of the ancient shore line, changes in profile and to a greater or less degree in horizontal configuration are sure to be wrought out by the waves. These operate to produce gulfs, beach ridges, and various forms of barriers. The spits, bars, and hooks, on the other hand are closely associated in genesis with the "long-shore" currents though they cannot be separated from the work of the waves and undertow. The region in question affords many interesting examples of the development of these land forms. Sand dunes also occur along the beach between Waukegan and the state line and in less notable forms at other points. The present shore line of this region may, for convenience, be divided into three parts: First, the section from Rogers Park to Winnetka; second, that from Winnetka to Waukegan; third, that from Waukegan to the state line. Along the second or middle strip of the coast line the lake has cut back beyond its earlier shores. North and south of it the initial beach ridges lie inland from the present lake and are steadily being encroached on and destroyed by the waves. Along the whole coast, except possibly for a few miles north of Waukegan, the present shore line is being cut back and in most cases so rapidly as to call for vigorous measures for protection of property. The present shore line is one of long sweeping curves, well established profile of equilibrium and landward encroachment, having all the characteristics of maturity. This is due, not simply to the work of the lake at its present level but in large measures to the smooth floor and even border which Lake Michigan inherited from its ancestors.

*The Record of Extinct Lakes, by J. W. Goldthwait*—Lake Michigan is the lineal descendant of the series of extinct lakes whose history is

recorded in raised beaches and terraces, abundant shore lines, and lake floor deposits higher than the present lake. The ancestral lakes owed their high level to the great ice sheet which acted as a dam across the northern side of the basins, holding the water up to the level of the lowest notch in the enclosing land basins. The cutting down of outlets or uncovering of new outlets at lower levels as the ice sheet melted northward, and uplift or tilting of the land, conspired to complicate the changes in level and outline of the lake during its early history. The Evanston-Waukegan district contains stretches of the abandoned lake shores in which one may read, somewhat imperfectly, the record of successive events of lake history. Various stages are recognized, including the Glenwood, the Calumet and the Tolston. The Tolston beaches fall pretty definitely into two divisions: The higher group, from 20 to 25 feet above the lake and the lower from 12 to 15 feet. Recent studies have strengthened the belief that the 15 foot member of the Tolston group of beaches does not mark the shore of a local lake, Chicago, but of two of its larger successors, Lake Algonquin and the Nipissing Great Lakes. Beaches and other evidences of these various stages in the early lake history are excellently displayed through the region, and are discussed in detail.

*The Development of Ravines, by W. W. Atwood*—When the ice melted the upland extended further to the east and presumably descended gradually to the level of the lake. As the rain fell on this new land, a part of the water sank in, a part was evaporated, and some collected in hollows or undrained depressions, while the remainder ran off over the surface. The land did not have a uniform slope to the lake, nor was the material perfectly homogeous. The surface water tended to gather into the depressions. Water so concentrated is in excess of that flowing over other parts of the surface, and therefore flows faster. Flowing faster it erodes the surface more rapidly, and as a result the initial depressions are deepened and washes or gullies are started. Once started, each gully becomes the cause of its own growth, for the gully developed by the water of one shower determines greater concentration of water during the next. Greater concentration means faster flow; faster flow means more rapid wear, and this means corresponding enlargement of the depression. Thus, gullies grow to be ravines and ravines become valleys. The first valleys started on a land surface would develop tributaries. These would widen and deepen and lengthen, cutting back the divides and eventually reducing the whole area to a lower plane. A series of rivers operating for a sufficiently long time might reduce even a high land mass to a low level scarcely above the sea. The time necessary for the development for such a surface is known as a cycle of erosion, and the resulting surface is a base level plane. The streams of the region show many excellent illustrations of the various stages of stream development.

*Underground Water, by W. W. Atwood*—In the farming districts within the Evanston-Waukegan area, ground water is reached in common wells at depths varying from 5 to 100 feet. At some places it is necessary to drill into the bed rock to secure a good water supply. There are two horizons from which artesian water is obtained. One

is reached at about 800 feet and continues downward for about 400 feet. The other is reached between 1300 and 1500 feet and continues several hundred feet in depth. The first is the St. Peters and the second the Potsdam sandstone. The water in these is derived from central and southern Wisconsin.

*Geographic Conditions and Settlement, by W. W. Atwood*—When settlers came to northeastern Illinois in the early part of the last century many of them selected the north shore region in preference to the Chicago district. The site of Waukegan was selected for a city before that of Chicago, and a small village and fort were established east of Highwood when Chicago was little more than a trading post. The region continues to be very attractive for summer homes, and large industrial interests have been established at Waukegan. Before the railroad was built there was a government highway from Fort Dearborn to Green Bay. In the southern portion of the district it was located on Beach Ridge. This old shore line formed an even grade where the land was drier and where the road material was sand and gravel. Ridge Road in Evanston is a portion of this old road. Through Wilmette it was unfortunately near the lake cliff and the original location is now more than 200 feet east of the present shore line.

The margin of the lake flat where the rolling upland begins is a favorite site for villages. In the Chicago region, Dyer, Indiana, Flosmoor, Chicago Heights, Homewood, Palos Springs, Palos Park, LaGrange, Galewood, and Norwood Park are at this margin. In the Evanston-Waukegan region there are not many such sites, but Winnetka has such a location on the south, and Waukegan on the north. The opportunity for a harbor, the lake flat for wharves and industrial plants, and the upland for the home district were important factors that influenced the selection of the Waukegan site. In the southern portion of the region the lowlands between the ancient beaches are largely used as truck farms. The ravine country east of the railroad between Winnetka and North Chicago is mainly devoted to suburban and summer homes.

### Suggested Field Trips.

*For the Study of Ravines and Valleys*—

1. Dead river between Waukegan and Beach.
2. Little Fork river, Waukegan.
3. Pettibone creek, North Chicago.
4. Near Glencoe.
5. Near Ravinia.
6. Near County Line station on the Chicago & Milwaukee Electric Ry.
7. At Beck's crossing, north of Glencoe.

*For the Study of Shore Features*—

1. Winnetka.
2. Ft. Sheridan.
3. South of Pettibone creek.

*For the Study of Old Beaches*—

1. From Evanston Lighthouse west on Central street.
2. At Winnetka.
3. From Waukegan north to State line.

*For Study of Dunes*—

1. Rogers Park near Calvary cemetery.
2. North of Waukegan or lowland.
3. On beach between Lake Bluff and North Chicago.

# STREAM IMPROVEMENT AND LAND RECLAMATION PROBLEMS IN ILLINOIS.

(By H. Foster Bain.)

## Contents.

## INTRODUCTION.

The recent increase in public interest in the various problems centering in our inland streams has nowhere been greater than in Illinois. Because of its geographic situation this State must always be largely concerned in any projects for the improvement of the internal waterways. The great lakes, the Mississippi and the Ohio all afford outlet for our commerce and the projected great lakes to the gulf deep waterway goes through the heart of our State. The people of Illinois have shown a lively interest in all that pertains to these waters and in the sanitary canal they have made a subsantial contribution to a great national system of public works.

That the problem is truly a national one is well understood. Taking up but one phase of it, swamp reclamation, it has been estimated that the swamp lands of the United States include 78,430,000 acres, nearly all of which probably may be reclaimed for agricultural use. Much of this land lies along the sea coast but a surprising amount is distributed over the upland and along the valleys of the interior. These lands form one of the most valuable of our unused resources. The fertility of morasses and of lands subject to overflow is well known and the monetary value and productive capacity of the submerged lands can hardly be over-estimated. These lands will be needed to sustain a great population, to maintain the steady increase in agricultural production that is necessary to continue prosperity, and to promote the best in American life and citizenship. The problems of their reclamation must be solved in the not distant future, and it is gratifying to note the new national policy of conservation and development of national resources. The passage of the national Reclamation Act of 1902 marked the beginning of improvement of the lands of the nation by national expenditure. It provided for the reclamation of arid lands in the western states. It now seems likely that in the near future the Government will take up on somewhat similar terms the corresponding work of the reclamation of swamp lands in the middle and eastern states. "The swamp lands of this country have occupied an important place in the public mind for more than half a century. In the beginning men sought lands that could be more readily converted to agricultural use, but as the value of the swamp and overflowed lands came to be recognized and opportunities of wealth which they offered were appreciated, they were sought and their reclamation begun. Congress encouraged their drainage by grants to the States. The first Act of this character was passed in 1849, and granted to Louisiana. 'To aid in constructing the necessary levees and drains,' all the swamp lands

within the State. Subsequent acts extended this grant to other states having swamp lands within their borders. In all there were granted to the states up to June 30, 1906, an aggregate of 63,324,318 acres of land classed as swamp. Under the provision of these laws, which are still in force, the states may demand that remaining swamp lands be patented to them as their character is determined. The United States Department of Agriculture in a recent report on swamp and overflowed lands estimates that ninety-five per cent of the swamp lands are in private ownership. The remainder is owned by the states or held in trust and subject to call by the states. The national government owns practically no swamp lands, but comprehensive efforts to reclaim these vast areas is rapidly becoming a national need, and the movement toward this end is one of the most important now engaging the attention of the American people. Reclamation involves coöperation. This has been secured through State laws providing for the formation of coöperative associations and districts and conveying the right of eminent domain. The rule has been to place the burden of the cost upon the land. The inability of the holders to meet the cost, together with unwise and lax laws, have operated to retard reclamation in most states where these lands lie. It is now proposed that the national government undertake the work of reclamation, providing the money and requiring its repayment in installments after the land has been rendered productive. The adoption of this plan will mean early commencement and rapid progress. It will mean the construction of flood control and drainage system that will be both adequate and complete and economical as to construction. It will mean the actual settlement of the lands reclaimed by men who will be actual settlers and home builders."*

Similarly the problem of stream navigation, of sanitation, of city and industrial water supply, of power development, indeed, all stream problems, have their national aspect. They are at the same time, however, State problems. Leaving for the present the discussion of the problems of the interstate streams along our borders and of the Illinois river, which is so intimately connected with any system of internal waterways, it may not be unprofitable to consider briefly some of the problems of the less well known intra-state streams. This involves consideration of the problems of (1) water supply for towns, villages and industries, (2) drainage, (3) navigation and power development.

## Problems of Water Supply.

It is the especial province of the State Water Survey and of the State Board of Health to consider problems of this class; a work which they are vigorously carrying on. The Geological Survey is only concerned with certain phases of these problems, relating especially to chemical denudation, and is coöperating with the organizations named in studies of the mineral content of the water of our various streams.

*The Great West, Sacramento, California, Feb. 22, 1908.

## Problems of Drainage.

*Early Condition of Illinois*—If one examine the accounts of the early exploration of Illinois he will be constantly impressed with the large amount of swamp land traversed. The impression gained in reading of the winter journey of Colonel Clarke, from the Mississippi to the Wabash, at the time he surprised and captured Vincennes, is that the soldiers waded in swamps from one river to the other. Yet, if one traverse the same route now, he will find, in the main, a slightly rolling upland well drained and cultivated, with so little water present that ponds must be made to furnish the boilers of the mills and factories scattered through our areas of cheap coal.

If again one examine the maps of the early land surveys, he sees acres and square miles of our central Illinoian corn belt set aside as swamp lands. The contrast between the territory as it now is, is so great as to have created the suspicion of fraud in the early surveys. Indeed, a few years since the United States land office sent special agents into the State to investigate matters and set at rest, if possible, these suspicions. These agents drove over miles of territory, the original maps in hand, and where swamps were marked by the surveyors, found only well drained, highly productive fields, beautiful groves, substantial barns and handsome houses. They were puzzled and suspicious but, in the end, after thorough investigation, reported no fraud. The explanation after all is simple.

Many years ago, some thousands in fact, the great glaciers came down from the north and spread over nearly all of what is now Illinois. In their coming they scraped and shoved along the rocks and soils of the territory invaded, and, when the warm sun melted the ice away, dumped their load in a vast irregular mantle over our older landscape. Our old Illinois is, therefore, buried 20 to 200 feet deep beneath a mass of rocks, bowlder clay, silt, and soil brought down from the north. The heritage of Canada, the soil patiently prepared by wind, water and sun acting through years on the rough rocks, has been spread out here with lavish generosity and now forms our great fertile prairies. The glacier, however, worked irregularly and, in dumping its load, paid little attention to existing stream ways. It filled up some, diverted others and created shallow ponds and deep "kettle holes" over the whole of a formerly well drained territory. Long as has been the period since the ice melted, it has not been long enough for the slow-eroding rivers to eat their way backward and to drain all these ponds and flat uplands. Only the early stages of river work have been accomplished. They have cut their deep narrow gorges, canyon-like in places, but have not developed the tributaries.

*Forming Drainage District*—Such a landscape affords the maximum favorable conditions for artificial drainage, and the people of Illinois were quick to see and to seize their opportunity. By the enactment of wise and far seeing laws, laws which have been a model to many other states, and which may well serve as a model to more yet, it was made possible for the people of individual areas, large or small, to organize drainage districts and to tax themselves for the reclamation of their

land. In a way the great Sanitary District, with its deep waterway, is only a large drainage tract and is only doing what many a modest farming community in many parts of the State has already done.

The drainage districts are permitted to organize, cut ditches, dig canals, build levees where necessary, and, in short, to aid nature in the extension of her streams, so as to carry off the surplus water and convert the swamps and ponds into corn fields and orchards. Above the open ditches the farmers bury long rows of tile, made at some nearby factory, and in a few years the increased yield of crops pays off the bonds, leaving a permanent benefit free of cost. In this way has been accomplished the miracle which puzzled the land inspectors, and in this way has been added millions of dollars to the permanent taxable wealth of the State.

*Ruining the Rivers*—It is an old and well established principle that water, usually so friendly and helpful, is none the less a natural enemy, and that each may protect himself and his land against its ravages as he will. Each land owner must accept and care for the water falling on his land or coming down on or across it in a natural stream channel. He may, however, in turn, send it on to his neighbor below and the neighbor must accept the consequences. Through all these years, not far now from a half century, our uplands have been drained by the simple process of hurrying the water on into the valleys. While there is no valid evidence that more rain is falling now than in earlier days, this hurrying of the water off the upland and into the valleys has produced congestion in the latter. Where once were clear open rivers with steady normal flow, suitable for navigation, there are now winding, brush-choked streams with abnormal flood and low water stages—streams that are useful only for the prompt carrying off of storm waters, streams which only accomplish this by the process of temporarily spreading out over the bottoms, preventing the cultivation of the latter and leaving behind muddy roads, ruined fields, and swamps, the natural breeding places of malaria-bearing mosquitoes. Such bottom lands are not only nearly useless, but are positive plague strips, dangerous to the health and comfort of the country at large. In Wayne county alone 82,000 acres were flooded ten times in 1905, and eleven times in 1906. Over much of the bottom land of the State crops are lost by reason of floods about once every 3½ years.

It is evident that under such conditions the communities affected suffer a heavy handicap. Land values are low, returns are uncertain and the great areas of standing water and swamp seriously affect health conditions. Nor can it be affirmed that these conditions are very rapidly changing for the better. It is true that vast areas of Illinois land have been excellently drained and rendered thereby highly productive. Lands in central Illinois which before drainage sold for $20.00 to $25.00 an acre are now selling for $100.00 to $150.00 and in special cases even more. In general, however, this is upland and while it does not surpass the lowlands in fertility it was more easily drained. The upland has been reclaimed by the simple process of

dumping the excess water into the valleys. The result has been a steady increase of floods, the inundation of the bottom lands, the choking of the stream channels and the gradual production of belts and strips of territory throughout the State which instead of being, as by right, centers of industry and progress, are unhealthy, poverty-stricken and unprogressive. The State has drained its upland farms but at the expense of the valleys.

*Illinois Bottom-Lands*—Nearly ten per cent of the State of Illinois is bottom-land and much of it is in the condition described. Some of this is at present worthless as a result of natural conditions; much of it is worthless as a result of the drainage and improvement of the surrounding upland. However, this is in the nature of things and a remedy rather than a grievance must be sought.

With a promptness and foresight which have ever characterized our people, attempts are already being made to correct these evils. If there is at any time or place too much water for the river to carry, the obvious remedy is to increase the carrying capacity of the stream. This may be done by widening it, by deepening it, by clearing the channel of obstructions, by cutting off the bends, straightening the channel and even in places by diversion. If the water overflows the low land the natural remedy is a system of levees, though these, by confining the water, raise its floods stage and further complicate the situation.

All of these means have been and are being tried in Illinois. In Fayette county alone a quarter of a million dollars has been expended along the Kaskaskia, and much yet remains to be done. In many other parts of the State similar work is being carried on.

*Some Examples of Reclamation*—Perhaps the largest single piece of work, as well as one of the most interesting, is that undertaken by the Green River Special Drainage District of Henry and Bureau counties. Here the tortuous channel of Green river is being widened and straightened for a distance of 40 miles so as to give a continuous channel of 90 to 120 feet top width, 60 to 80 feet bottom width, and 10 to 20 feet deep—a no mean waterway. It is estimated that this will result in reclaiming 45,000 acres at a total cost of $600,000, including laterals, right-of-way and damages. The main ditch is 23 miles long and the total excavation is estimated to amount to 4,000,000 cubic yards.

The Salt Creek Special Drainage District lies in Menard and Mason counties and is working to straighten a stream which flows into the Sangamon river. Naturally the stream meanders through 23 or 24 miles. The corrected channel will be 11 miles long and will have a top width of 60 feet, bottom width of 40 feet, and depth of 11 feet. The estimated cost of this work is $79,000.

In many areas it is not sufficient to merely straighten the channel of the stream, thereby increasing its fall per mile and its resultant capacity to handle the flood waters, but levees must be built as well to protect the land from overflow. The best known levee district probably is the Sny Island Levee Drainage District organized under a special Act in 1879, the forerunner in fact of all our drainage laws. Along the Illinois valley a number of similar districts have been organized;

in places the land must not only be protected from the river but also from water originating back of the levees in hillside drainage. This water is often pumped up and out into the main stream, and large pumping plants are installed and maintained for this purpose. That of the Spring Lake District cost $30,000, and even more expensive ones will doubtless be built in time.

Practically all the ditches are now dug by great dredges which are everywhere eating their way through the prairies or working diligently along the streams. These are of varying capacity and type according to the nature of each piece of work. One firm, that of G. A. McWilliams, has now seven such dredges at work, five in Bureau and Henry counties and two in LaSalle. If all the dredges now working in Illinois were gathered together they would form a fleet numerous enough at least to attack the digging of the Panama canal.

Drainage work such as this is usually financed in part by cash tax levy assessed on the land benefitted and in part by bonds. In the case of the Green River District 42 per cent of the cost was met by direct tax and the remainder by bonds which sold at 4¾ per cent. In other cases 5 per cent and even higher rates of interest have been paid. Everywhere, however, the principle is maintained that by spending money on improvements, permanent values are created far exceeding the amounts expended.

*Area of Land to be Reclaimed*—Large as are some of these projcts they are small in comparison with the amount of work still to be done. The following estimates of the areas of bottom land along a few of the inland rivers of the State made for the State Geological Survey by Mr. W. Carvel Hall, will indicate something of the magnitude of the problem.

BOTTOM LANDS SUBJECT TO OVERFLOW IN ILLINOIS.

| River. | Estimated valley length. Miles. | Estimated area of bottom land. Square miles. |
|---|---|---|
| Embarrass | 65 | 175 |
| Little Wabash | 85 | 335 |
| North Fork Little Wabash | 20 | 45 |
| Skillett Fork | 40 | 190 |
| Olney Fork | 17 | 15 |
| Saline River | 25 | 30 |
| Big Muddy | 50 | 45 |
| Kaskaskia | 65 | 245 |
| Silver Slough | 22 | 30 |
| Shoal Creek | 25 | 40 |
| Crooked Creek | 7 | 5 |
| Sangamon | 80 | 100 |
| Salt Creek | 15 | 20 |
| Desplaines | 285 | 900 |
| Rock | 80 | 275 |
| Spoon | 60 | 30 |
| Mackinaw | 30 | 25 |
| Pecatonica | 45 | 45 |

In this table are included only those streams which were unsurveyed. If to the areas estimated are added the bottom lands of the Illinois and its branches, surveyed by the U. S. Army Engineers in 1905*

*House of Rep., Doc. 263, 59th Congress, first session.

and the Cache river bottoms surveyed by a State commission in 1904* the totals would be much greater. Preliminary surveys have already shown that Mr. Hall's estimates are well within the truth since on the Kaskaskia alone nearly 300 square miles of bottom land are now known. The table however, will serve its main purpose in illustrating the extent and something of the distribution of the bottom lands of these streams.

The great interstate rivers which border Illinois, the Mississippi, Ohio, and Wabash, have also extensive bottom lands. Mr. Hall estimates that in Illinois their areas amount respectively, to 1205, 25 and 270 square miles.

Probably 90 per cent of the bottom lands of the State are unprotected or inadequately protected against floods and it is estimated that if they could all be brought under successful cultivation there would be added to the farm values of the State over one hundred fifty million dollars. There would be additional benefits to be derived from improved health conditions, some power development and the increased navigability of the streams.

*The State's Interest in Reclamation*—In order properly and economically to plan works which shall protect and drain the river bottom it is necessary to take into account the river as a whole. Power development must not be allowed to interfere with navigation and one drainage project must not be allowed to block the way for a more comprehensive one. No permanently satisfactory solution of the problems afforded by even one of these streams is likely to be reached except by the united action of the people of a whole valley. Large districts must be arranged and in order that they may work most efficiently, it will probably prove necessary for the State to assume at least supervisory control of the work. The State is, in fact, under certain obligations to do this. The lands, originally in possession of the general government, were given to the State upon condition that they be drained. This obligation was passed on to the counties, drainage laws being provided to permit of the work being executed. Since now a stage in the work has been reached where a considerable change in method is necessary, the State must assume its share of the burden.

A beginning has been made. In 1903 the General Assembly provided for a special survey of the Cache river bottoms. In 1905 the General Assembly passed the following joint resolution looking to the improvement particularly of certain of the rivers in the southern part of the State.

### KASKASKIA, WABASH AND SANGAMON RIVER IMPROVEMENT.

WHEREAS, There is a large amount of overflowed and waste land in its present condition along the Kaskaskia, Embarrass, Little Wabash and Sangamon rivers and their tributaries in the southern part of the State of Illinois, which by combined and judicious management might be redeemed from overflow and become the most fertile and productive part of the State, and made more sanitary; and,

*Report of Board of Cache River Drainage Commission of Ill., 30 pages, Danville, 1905.

WHEREAS, The citizens along these several streams are desirous of procuring such legislation as will enable the owners of the lands adjacent to these rivers to improve the same; and,

WHEREAS, Unless these improvements are made from the outlet to their heads the improvements can not be successfully and judiciously made anywhere between the head and mouth of such streams, now, therefore, be it

*Resolved, by the Senate, the House of Representatives concurring herein,* That any two or more counties, or any two or more cities, interested in the improvement of these streams, be requested to organize in their respective counties, and upon these respective streams, and appoint such committees as may be deemed advisable in the premises, to make an investigation of the situation along these streams, and make an estimate of what improvements could be judiciously made, and where required to be made, and the probable expense of making the same, and tabulate their respective work in such particulars, and prepare a statement to be submitted to the next General Assembly, respecting the proposed improvements, and what legislation, in their judgment, is necessary to bring about the desired result; that such committee be authorized to make these respective investigations at their own expense and submit the same to the next Legislature through their respective representatives and senators; and be it further

*Resolved,* That the General Assembly, recommend that the respective boards of supervisors of the several counties interested in this work, make reasonable appropriations to pay the expenses of these various committees.

Adopted by the Senate, March 30, 1905.

Concurred in by the House, May 3, 1905."

No definite results having been accomplished under this resolution the General Assembly in 1907 made a special appropriation to the State Geological Survey for the survey and study of lands subject to overflow along the streams of the State. At the same time an additional appropriation was made to the Internal Improvement Commission for the further study of the rivers of the State with a view especially to their improvement from the point of view of navigation and the development of power. The State has therefore undertaken as its share the expense of the surveys, the studies and the supervision of the work and in appropriating for the Shawneetown levee has even set the precedent of at least some appropriation for construction work.

## PROBLEMS OF NAVIGATION AND DEVELOPMENT.

*Possible Power Development*—The problem of the streams is not one of land drainage only. While they are all important as affording outlet for the various drainage systems both upland and bottom land, the streams have important values as sources of power. Mr. Lyman Cooley has estimated that the streams of Illinois are capable of furnishing an approximate total of 350,000 horse power. Very little of this is as yet being realized and indeed only a few of the streams have been systematically studied with power development in view. The Internal Improvement Commission is now engaged in making such studies.

*Improvement of Streams for Navigation*—The importance of our intrastate rivers as regards water navigation is not generally appreciated. A comprehensive system of inland water ways must take account of the tributaries as well as the main streams. A transportation system of any kind which makes no provision for branches and feeders is foredoomed to failure. In the case of a river transportation system this

is particularly true since the tributaries serve not only as arteries for the collection and distribution of freight but also furnish the water to the main stream. Upon their proper regulation depends the maintenance of an even stage in the main streams; and this is of first importance to the development of great trunk channels of transportation.

Engineering work along the streams should therefore take into account the possibility of development of values of all sorts. In the ideal system of imponding the flood waters by means of numerous dams on the smaller streams, three great objects may be accomplished at once:

(1). The flood waters may be saved for use during low water stages of the river, thereby promoting navigation at the same time that destructive floods are prevented.

(2). In the course of their outflow they may be used to generate power for industrial purposes of all sorts.

(3). By storing the flood waters and rectifying the river channels the bottom lands may be largely drained and reclaimed.

Just how far this may be possible along the various streams of the State can not be told in advance of the completion of the surveys now being made. There will doubtless need to be many and radical changes to meet the needs of individual streams according as the value of the land for farming, of the water for power, or the stream for navigation is most important in each case. To decide these matters careful engineering studies are necessary; such studies as are now being carried out.

*Freight Traffic Available*—If the streams be suitably improved it seems likely that they may be of large service in navigation. The Sangamon, the Kaskaskia and the Big Muddy, extend into three of our greatest coal fields. It should be possible to ship coal by barges from Illinois as readily and much more cheaply than from the Pittsburg district which now makes large shipment to lower river points and occassionally to Havana and other foreign Gulf ports. At present at certain seasons all three of these streams are navigable for short distances above their mouths by river boats and by gasoline launches throughout many miles. Formerly steamboats loaded at Vandalia on the Kaskaskia and at corresponding inland points on the other streams and it should be possible to add materially to the present mileage of navigable water. To the south and west of Illinois is a large area, extending down into Mexico, where fuel requirements are beyond local supply. This area can be readily reached by barge lines delivering to the east-west railways or to points on the streams or the Gulf and a most important system of traffic seems likely to develop.

The southern portion of our State also contains great quantities of limestone suitable for grinding for fertalizer or in connection with adjacent clay beds for making into Portland cement. As the latter is being used constantly in increasing quantities we may confidently expect shortly to see it manufactured here on a large scale. Cement and the miscellaneous mineral products of the area would furnish a large amount of the bulky, slow freight which is best shipped by water.

Southern Illinois is at the same time a great agricultural territory; wheat in particular being a staple crop. Even now the surplus is to

some extent shipped by small steamers operating on the Ohio and Little Wabash but with the development of a great interior system of stream ways suitable for barges and tugs, a much larger traffic ought to be built up. These are only a few of the possible lines of traffic. Many others will readily suggest themselves.

## Work of the State Committee on Waterways Reclamation.

To consider the various problems involved in river improvement in Illinois there has been organized a State Committee on Waterways Reclamation including representatives of the State Geological Survey, the Internal Improvement Commission and the U. S. Department of Agriculture. The work of this joint committee is expected to result in a report upon which the General Assembly can formulate a definite policy toward stream improvement.

The making of detailed maps of the different river valleys has been assigned to the Geological Survey and is now being carried on by methods described elsewhere in this volume by Mr. E. W. McCrary. The methods used are essentially those developed by the U. S. Geological Survey which is actively coöperating in the work.

Work is now being carried on along the Kaskaskia, Big Muddy, Embarass, and additional work along the Little Wabash and the Sangamon is planned for 1908. The special study of drainage problems will be undertaken by the U. S. Department of Agriculture under the direction of Mr. C. G. Elliot, Chief of Drainage Investigations. Work has already been taken up along the Little Wabash river.

The Internal Improvement Commission is making the general engineering studies involved, including the gauging of the streams in which part of the work the assistance of the Water Resources Branch of the U. S. Geological Survey has been enlisted.

# TOPOGRAPHIC MAPPING OF BOTTOM LANDS.

(By E. W. McCrary.)

The last General Assembly of Illinois made a small appropriation for the beginning of surveys and studies of the over-flow lands of the State, for the purpose of acquiring a knowledge of their existing conditions, and the methods by which the needed improvements may best be made. In accordance with this legislation, the State Geological Survey last year began the topographic mapping of portions of the Kaskaskia, Big Muddy and Embarass rivers, in which it coöperated with the topographic branch of the U. S. Geological Survey. Coöperative topographic mapping having been arranged in quadrangles adjacent to these streams, much of the control work of the regular surveys, has, with slight modifications been utilized for our special drainage work. This has enabled us, at the least possible expense, to produce during the past season a 5-ft. topographic map on a scale of 1:24000 of approximately 200 square miles of these river bottoms.

The purpose of the Survey in doing this work along the river courses is to furnish a detailed topographic map, sufficiently accurate to be of practical value to the engineer in the planning of any proposed improvements and the estimating of costs for same. While the question of the scale has been somewhat perplexing, it is believed that the 1:24000 scale will prove adequate for the uses for which it is intended, since it is sufficiently large to contain all detail that would be taken into account in the planning of these improvements. It has the additional advantage of permitting large sections of country to be mapped on a single sheet of paper, thereby presenting in a collected form the conditions in different sections of the bottoms. Also because of its much reduced cost, which must be considered with a limited appropriation, it has a very strong claim to consideration.

The section of country especially referred to here, and which may be considered in a general way as representative of the over-flow lands, is that portion of the Kaskaskia river bottoms mapped last year, extending from Keyesport on the northern boundary of Clinton county to its outlet near Chester. Within this area, the field work has been completed south to near the boundary line between Clinton and St. Clair counties including a total of 160 square miles, while the level and traverse work has been completed for the remaining portion to the mouth. Of the 160 square miles of mapped country, 130 square miles are under from 1 ft. to 8 ft. of water several times each year.

The overflow season usually begins in January, and at times lasts as late as the middle of August, which makes the season, in which the land is dry enough for cultivation, entirely too short for successful farming. It seems to be a generally necessary to plant several times each spring, and even with the last planting they cannot hope for a yield to the full capacity of the land. It has been stated that a successful crop, one that has escaped damage by the flood, does not occur oftener than once in seven years. In fact, so completely is this river in possession of its bottom lands that very little effort is made to utilize it in any way, and at the present time it might well be considered mere waste land.

In making a study of these rivers, it is well to bear in mind that their present condition is not altogether due to natural causes, but that the making of drainage improvements in other parts of the State, is to a great extent responsible for their present trouble. More than 25 years ago, after a practicable demonstration of the successful drainage of farm lands by tiling, the central part of the State began an earnest and persistent fight for the reclamation of their swamp and wet areas. The vital question of sufficient outlet naturally followed, and by individual effort, by the formation of drainage districts, and with other help, canals were dredged and natural channels straightened and improved. These, with innumerable ditches of smaller capacity, now quite thoroughly provide for the disposition of the water from tiled fields. This quarter of a century of sustained effort on the part of the farmers of the State, during which millions of dollars have been spent on drainage propositions, has resulted in a most thorough system of successful drained farm lands. So thoroughly has this work been accomplished that it might be said that Illinois, with the exception of a few areas, such as the Kankakee Marsh, and the Green river country, has reached almost the last stages of a complete drainage system for the State. Important exceptions also, are some of the rivers, part of which form its boundaries. This final step, however, presents by far the greatest problems for the engineer, and their successful solution can be obtained only after a very thorough examination of all conditions which bear upon the question. The localities now needing outlet are to be found in the lower stretches of the principal streams of the State, the Kaskaskia, Little Wabash, Big Muddy, Embarass and Sangamon being especially important.

Before the uplands were reclaimed by tiled drains, a rainy season of even a week's duration, produced but a slight increase in the flow of the channels of these streams. This was due to the fact that the rain collected in enormous areas of marsh and lowlands, and reached these river courses by a very slow and tedious process. The experience of the past summer, while making topographic surveys along the Kaskaskia river, shows that a rain of 24 hours will now raise the stream from 4 to 10 feet. An explanation of this is readily found in the fact that with our present system of tile drainage and the excellent outlets thereto, water from such a rain is carried quickly from the fields and poured immediately into the upper courses of these streams, and the

multiplication of these feeders has forced upon the streams a burden entirely beyond their present capacity. As a result the numerous floods have rendered thousands of acres of the best farming land of the State practically worthless. It will be easily seen that the responsibility for the improvement of the channels of these rivers rests equally upon the farm holders on the upper courses of these rivers with those located nearer their outlet. The principle of general assessment, so thoroughly recognized in legislation providing for drainage districts can be applied with justice to these larger problems of reclamation which cover all land within individual drainage basins.

The methods used in making these drainage maps are very similar to those of the topographic branch of the U. S. Geological Survey, the principle difference being that because of the contour interval used the enlarged scale, and the object of the work itself, a greater amount of detailed work is necessary. As bases for our maps we have the primary traverse transit lines of the U. S. Geological Survey for position and the primary level lines of the same survey for elevation, in addition to which we have the steel tape measurements along township lines. With these lines for control, a plane table buggy traverse is run of the first ridge road outside the bottom on each side of the river, and as often as possible cross roads, which tie the work together, are run in the same way. Since the distance between roads crossing the river is so great, it has been found necessary, at intervals of from 1½ to 2 miles, to traverse from the outside roads to the river, where points are left for the purpose of being tied to by the stadia traverse of the river. While the wheel method of measurement may be considered crude and inaccurate, a practical test will prove, that for scales even longer than the one used in this work, and controlled equally well, it will fully meet all requirements. The accumulation error is slight, and when larger errors are made, they are readily located after the traverse has been tied to itself or to another line.

Over the same roads, and others when necessary, spirit levels are run and numerous elevations painted at summits, bridges, road corners and other convenient points, while at intervals scarcely exceeding a quarter mile, substantial bench marks are left. The level work is so planned that elevations determined by stadia, need not be carried for distances greater than 1½ miles. Experience during the past summer indicates that levels may be successfully carried with this instrument for distances of 3 or 4 miles. The instrument used is a similar to the ordinary stadia, except that it is provided with an attachment which simplifies the reading of elevations at an angle. It has been in use on the U. S. Geological Survey the last few years, the idea for the improvement having originated with members of that survey.

The frame work of traverse and level lines, together with the stadia traverse of the river and other streams, is adjusted to the land lines and the other available control after which it is ready for the topographer. This topographic sketching is by far the most difficult work connected with the making of a map, because of the necessity of carrying innumerable stadia lines through the dense jungles of the bot-

toms. Starting from convenient bench marks, these lines zig-zag through the bottoms, the sight being through the openings of greatest length in the general directions of the traverse. The importance of these lines being closely run is clearly shown by a glance at the finished map, for the great number of lakes, sloughs, marshes and isolated hills are features that can not be reliably mapped except by actual survey. Being hidden, as they are, by dense woods they must be hunted, and the meandering traverse line is the method by which we find them.

On our drainage maps, such features have been carefully traversed and their elevation determined, and in addition to the numerous cross sections at short intervals, a mass of isolated elevations have been left throughout the bottom lands. These stadia lines, as carried through the bottoms, are usually run with great difficulty because of the heavy undergrowth, and especially is this true in mid-summer, when, in addition to the dense foliage, the intense heat and mosquitoes make work both difficult and disagreeable. In fact, because of this condition in the bottoms, the problem of keeping help is a very serious one and the best solution seems to be in the bringing of help from such a distance that quitting at will is made more difficult. Few men will submit long to the physical sufferings met with in the bottoms, even at wages from two to three times the price they can receive elsewhere, if they are where they may reach home within a few hours.

Along with the stadia traverse and levels, the relief of the river bottoms and the country adjoining the bottom lands has been carefully sketched. This map of the relief with 5 feet contours should greatly facilitate the study of the river problem. Mere location of the stream course and elevations, be they ever so numerous, does not bring to the eye of the engineer the actual figuration of the surface. It is thought that it will be necessary to inspect most minutely the local physiographic conditions before a successful plan of improvement can be determined. It has been planned, therefore, to present to the engineer who studies this great problem the most complete possible data for his use. It is not claimed that this form of map is the most inexpensive one even under favorable conditions under which it was accomplished last season but it is believed that in the end it will justify itself on the ground of economy in the saving of time and of additional work for the engineer. It also seems that in a study of the carrying capacity of the channel, the effect of possible dike construction and of the control of lateral streams, the topographic features of the map will appeal very strongly to the engineer.

# DRAINAGE ABOUT SPRINGFIELD.*

(By J. Claude Jones.)

Lying as a blanket over the surface of the area about Springfield is a heterogeneous mixture of clay, sand, gravel, and other unconsolidated materials varying in depth from 10 to 60 feet or more. Most of this material is glacial drift, deposited by a former sheet of ice, or continental glacier, which covered an area several million square miles in extent, most of which lay north of central Illinois. If the drift were taken away, the surface of the underlying bed rock (shales, sandstones, and limestones) would be found to possess a topography en-

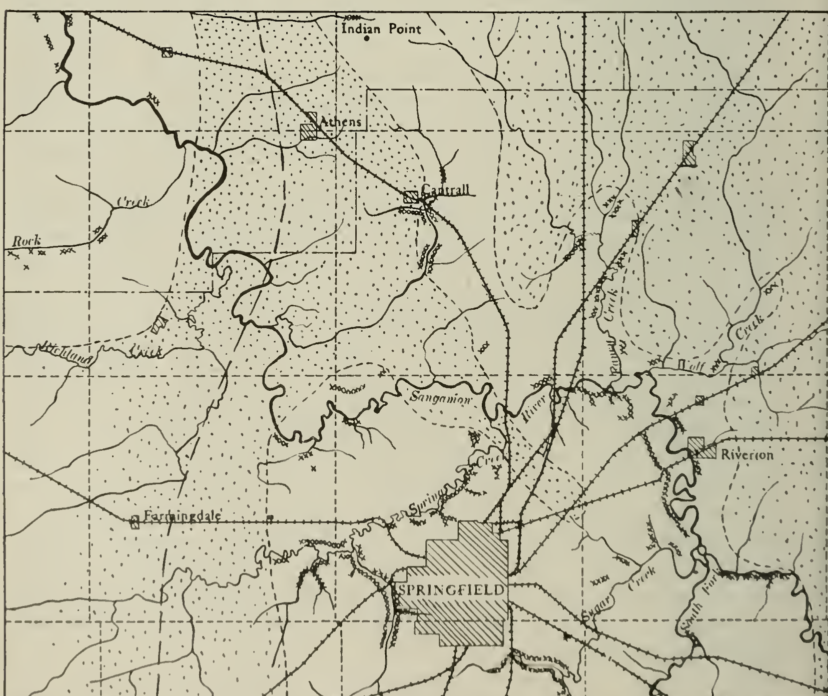


Fig. 1. Sketch map of an area about Springfield, showing the relation of present drainage to pre-glacial topography. The crosses indicate rock exposures, the dotted areas represent pre-glacial lowlands, and the unshaded areas represent pre-glacial uplands.

tirely different from that of the present surface. The valleys of the rock-surface would not correspond with those of the present surface, and the hills and ridges of the rock would have little relation to the

* From an educational bulletin in preparation.

hills and ridges of the land as we now see it. This is known by the following facts: Many wells of the region are deep enough to penetrate the drift to the rock below. Knowing the depth to rock at numerous points scattered over the area, it is possible to reconstruct, in a general way, the configuration of the rock surface. This rock-surface corresponds, in a general way, with the former land surface.

From well borings, it is known that there was a low upland plain about twelve miles broad, in the area south of Springfield.

This plain was so nearly flat, that the altitude of its surface varied only a few feet. The plain extended northward to a point a little beyond the present westward course of the Sangamon river, becoming slightly narrower in this direction. Beginning a mile or so east of Springfield a small valley, running in a northwesterly direction, divided the plain into two parts. The western part terminated about a mile north of the Sangamon (Fig. 1), but the eastern part with a width of two miles or so continued north-northwest as a low ridge east of Cantrall and Athens, beyond the limits of the area in question. The remnants of two or three minor valleys may be traced on the eastern side of this ridge. They headed near its crest, and ran towards the northeast. To the north and east of this plain, the surface descended gently at the rate of about ten feet to the mile.

West of the upland plain referred to there was a broad valley whose bottom was about one hundred feet below the crest of the plain. The axis of this valley passed northward just east of Farmingdale in a broad sweeping curve, and, turning slightly to the west at Athens, continued on for an unknown distance. West of this valley, which may be called the Athens valley, the ground rose gently and culminated in a low swell centering about Rock creek. The height of this swell was about the same as that of its counterpart east of the Athens valley. The rise of the western border of the valley directly west of Springfield was not so rapid as in the Rock creek region, and was quite definitely separated from it by a rather abrupt slope along a line corresponding approximately with the present course of Richland creek.

The Athens valley narrows somewhat towards the north, and apparently becomes deeper in the same direction. Wells have not reached the surface of the rock at its bottom, however, and it is not possible to state its exact depth. As the general slope of the old land surface is known to have been northerly, it is probable that the drainage was in that direction.

The explanation of the narrowing of the valley down-stream is found in the character of the bed rock of the region. This bed rock is for the most part soft shale and sandstone which offer relatively little resistance to weathering and the erosion of streams; but in the areas about Rock creek and Indian Point, a few miles west and north of Athens, more resistant limestone is found. The rock is in beds which are nearly horizontal, though with a slight dip to the east. Consequently, as the Athens river flowed through this area, the limestone resisted erosion, and the valley did not become so broad here as in the softer shales and sandstones farther up-stream.

The difference in height between the highest and lowest points on the old rock surface in the Springfield area is about 40 feet, so far as now known. This amount of relief is about the same as that of the present surface of the land. On the rock surface, however, all the slopes were gentle, a slope of more than ten feet to the mile being the exception. The rock surface, before the drift was deposited upon it, was therefore, a broad, nearly featureless plain, as flat and monotonous as the present day prairie in areas back from the immediate valleys of the streams. It is probable that the old land surface, that is, the rock surface, covered by a thin body of soil and subsoil, had been exposed almost continuously to the action of the weather and streams since the close of the coal forming period, millions of years before the glacial epoch. During this long period the streams had worn down much of the surface about as low as they could wear it. The valley flats were wide, and the divides between the valleys relatively low, and their slopes gentle.

Then came the continental glacier which lay long upon the land, burying it under hundreds of feet of ice. When it finally melted away, it left the drift upon the surface, for the drift is nothing but the debris which the ice had worn from the surface a little farther north. The drift left by the ice filled the old valleys, and covered the low upland with ten to twenty feet of stony clay, sand, and other glacial materials. So completely was the topography of the old surface effaced by the deposits of the ice, that it would have been impossible to judge, from the present surface, where the old valleys and the old hills were. In the place of the old divides and valleys, the ice left the uneven surface of the drift characterized by low mounds and irregular depressions scattered helter-skelter over the surface, none of them of great height or depth.

As the rain fell it filled the depressions and overflowed their lowest points. Drainage lines were thus gradually established from one depression to another, and these drainage lines became the present valleys. As the depressions on the surface of the drift had no relation to the former surface buried beneath it, the courses of the streams had no relation to the previous valleys. They crossed the buried ridges and valleys indiscriminately. By referring to the accompanying map (Fig. 1), it will be seen that the Sangamon river, for instance, crossed the old buried Athens valley diagonally, and the eastern spur of the upland nearly at right angles. Spring creek flows easterly across the Athens valley, and half of the upland to the west, before joining the Sangamon. Fancy creek and Wolf creek flow from the eastern slope across the upland to join the Sangamon. The drainage in this particular area dates from the withdrawal of the ice, and is therefore entirely post-glacial, and, so far as is now known, none of the pre-glacial drainage lines serve the present streams.

As the streams cut their valleys down through the drift, they reached the rock first at the points where the drift was thinnest. These points were over the former divides, and the streams, continuing their cutting, cut on down into the rock, and at such places rock is exposed in the banks of the streams. In the former valleys, the streams have not

yet cut through the drift, and here no rock appears. As a result, the banks of all the major streams of the region are of rock in some places, and of drift in others.

The subsequent history is brief. At a later time, a second ice sheet extended southward from Lake Michigan, without reaching Springfield. Its western border lay just west of Decatur, and it covered the upper part of the basin of the Sangamon river. The river, swollen by the waters of the melting ice, carried large quantities of debris down the valley. Much of this debris, consisting of gravel, sand, and silt, was deposited in the bottom of the valley, building it up considerably above its former level, and several feet above the level of its present flood plain. The mouths of the valleys tributary to the Sangamon were built up at the same time to the same level. From the bare surface of the sands and silts, the winds caught up some of the finer materials and blew them up the valley-slopes and out upon the surface of the adjoining prairie, leaving them there in the form of hills and hillocks of sand called dunes. Later, vegetation got a foothold on the dunes, and prevented the further shifting of the sand by the wind.

After the later ice-sheet melted from the region, the streams recovered from their overloaded condition, and began clearing away the sediment they had recently deposited in their valleys. This has progressed so far that, at the present time, there are only a few remnants of the filling made by the drainage of the last ice sheet. These remnants are the "second bottoms" or terraces in sheltered parts of the valleys. The best preserved area of this sort is across the river from Petersburg, although another a mile south of Riverton is nearly as good. On the surface of these terraces lie the dunes last formed, now covered by vegetation, and therefore fixed in position.

It is clear from the foregoing that the configuration of the surface was developed during and since the glacial period. It is therefore of relatively recent origin, for though the ice melted from this region many thousand years ago, even this date is a very recent one as the geologist reckons time.

# THE ROCK BED NEAR WHEATON.*

(By Arthur C. Trowbridge.)

The area about Wheaton is covered by a mantle of stiff, stony clay, with occasional patches and layers of sand and gravel. The average thickness of this body of material, called drift, is more than 100 feet. The drift was deposited by the Continental glacier (or glaciers) which formerly covered this region, together with a large part of the northern portion of North America. Below the glacial drift lies solid rock, which is often reached by wells. The shape of the surface of the rock below the drift would be known, if we knew the elevation of the surface, and the depth of the drift at all points. It is true that numerous wells have been dug or bored down to bed rock, but the wells which go down to the rock are so scattered that there are considerable areas where its surface has not been reached. Though there are not deep borings enough to give us detailed knowledge of the surface of the rock, there are enough to give us much information about it.

The surface of the bed rock is known to lie at various depths below the surface. In a few places drift is absent, and in one place it is known to be 178 feet deep. In general, the bed rock comes nearer the surface in the western and southwestern parts of the region than in the more extensive central portion. There is a considerable area around Naperville, where the rock lies only a few feet below the soil, and it comes to the surface at several points. In the southwest part of Naperville, on the south bank of the west branch of the Dupage river, there are three large old quarries in the limestone, and the rock outcrops along the banks of the river for some distance up and down the stream. A mile south of Naperville in the northwest quarter of section 30, Lisle township, a small patch of bed rock appears at the surface, where it was uncovered for quarrying purposes many years ago, though little rock was taken out. A mile north of Eola Junction, the bed rock was found at the bottom of a ditch made for field tiling. Rock also appears at the surface at Elmhurst, two miles east of the eastern edge of the quadrangle, where an extensive quarry is now in operation. The drift is thickest, so far as known, in Bloomingdale township. It is 174 feet deep at one point in the south-central part of section 28, and 178 feet at another point close by. In the east-central part of section 22, the depth at the site of one well is 171 feet.

*Extracts from an educational bulletin to be published later.

The average depth of the drift for the whole region, as indicated by sixty-one well records, is 115 feet. The average depth of drift as shown by five wells along the west side of the area is 71 feet. The average of seven wells along the east side gives 99 feet, while the average of forty-nine wells in the large central portion gives 121 feet. The relations between the present surface and the surface of the bed rock are brought out in a general way in the diagram below:


FIG. 2. A generalized diagramatic section across the Weeaton Quadrangle, from east to west, showing the glacial drift overlaying the rock beneath. It will be seen that the configuration of the present surface has no definite relation to the configuration of the surface of the rock. Length of section 14 miles. Vertical scale exaggerated about six times.

Some well drillers of the county say that the rock surface is practically level, and that the distance to bed rock in any place can be computed beforehand if the elevation of the well site is known; but the study of the well records does not bear out this conclusion. By reading the elevations of well sites from the topographic map, and subtracting the distance to rock, we get the elevation above sea-level of every point on the rock surface to which a well has been bored. Such an estimate for sixty-one wells shows the surface of the rock to be quite irregular in a small way, though with no great amount of relief. Ten well records chosen at random from different parts of the area afford the following data:

| Elevation of surface above sea-level—feet. | Depth to rock—feet. | Elevation of rock surface above sea-level—feet. |
|---|---|---|
| 745 | 170 | 675 |
| 755 | 140 | 615 |
| 755 | 108 | 647 |
| 775 | 124 | 651 |
| 695 | 87 | 608 |
| 750 | 130 | 629 |
| 780 | 116 | 664 |
| 715 | 103 | 610 |
| 760 | 77 | 683 |
| 690 | 87 | 603 |

It is seen from the above table that the pre-glacial surface had irregularities enough to give it a somewhat uneven appearance.

No attempt has been made to determine the details of the preglacial surface, but some general observations concerning it may be in order. The lowest points found on the surface of the bed rock are but 580 feet above sea-level, or about the same as the surface of Lake Michigan. This elevation has been found in two places, one in the south-central part of section 23, Winfield township, and in the central part of section 3, Bloomingdale township. The highest part of the rock surface, so far as known, occurs at the Naperville quarries, where it reaches an elevation of approximately 680 feet. The rock surface in the region therefore has a relief of at least 100 feet. Its relief is probably somewhat more, because it is not likely that the highest and lowest points of its surface have been touched by borings. The two extremes in elevation at Naperville and in Winfield township are six miles apart, giving an average slope of 100 feet in six miles. In section 21, Bloomingdale township, a well at an elevation of 815 feet struck rock 140 feet from the surface, while one hardly a quarter of a mile away, where the surface is 15 feet lower, reached rock at a depth of 158 feet. At this place the relief of the rock surface is at least 32 feet in a quarter of a mile. Between Naperville and the canning factory at Eola, five miles away, there is a difference in elevation of the rock surface of 80 feet. The maximum relief of the present surface is about 220 feet, or 120 feet more than that known for the rock surface. So far as now known, there is no slope on the rock surface as steep as many slopes on the present surface.

It is found from six records that the rock along the western edge of the area has an average of 675 feet above sea-level; under the terminal-moraine-like belt a little farther east, the surface of the rock, as indicated by borings, has an elevation of about 622 feet; under the ground moraine covering the greater central part of the region, its elevation is about 639 feet, and along the east edge of the area about 629 feet. This would seem to show that the highest part of the area in pre-glacial times was along its western side, where the present surface is lowest. The highest part of the present surface is along the terminal moraine east of the outer edge of the area. The lowest places today are therefore over some of the higher parts of the old rock surface, and the higher parts of the present surface, overlie the depressions of the rock surface.

An attempt is made in the figure to show the relations of the two surfaces by a section showing the form of the present surface, a very generalized profile of the rock surface, and the relations of the two to each other. As the topography of the lower surface must be made up from the well records alone, it is somewhat conjectural, and lays no claim to accuracy in details.

It appears then that the rock surface does not differ profoundly from the drift surface, although it had less relief, was not quite so rough, and was about a hundred feet lower. It is probable, however, that the old surface was distinctly different from the present one in the arrangement of its elevations and depressions. The present surface is due to the deposits left by the ice sheet, and the elevations and depressions have no regular arrangement, while the old surface, being shaped largely by stream erosion, doubtless had its elevations and depressions arranged with respect to the streams which made them.

From the meager data available, it seems that the surface of the rock was not everywhere greatly eroded by the ice before the drift was deposited. The line between bed rock and drift at the Naperville quarries is a sharp one, showing that enough erosion had taken place before the deposition of the drift, to remove any soil which formerly existed on the bed rock. But the surface of the rock here is not striated, nor does it show any of the characteristics of a surface strongly eroded by ice. In three places where the drift was removed so as to expose the rock surface freshly, the latter was found to be affected by minor irregularities due to weathering; but as the rock was uncovered only where the drift was thin, it is possible that this weathering took place since glacial times. At the outcrop a mile south of Naperville, the plane between drift and bed rock is made vague by loose angular fragments of the limestone, which grade into the typical drift above. But the drift here is only two feet thick, and weathering since the ice melted may have affected the rock below it. Neither here or at Naperville is there any evidence of strong erosion by the ice. Deposition seems to have been the main work of the last ice-sheet in those parts of the region where the rock surface is to be seen. It does not follow, however, that this was the case in all parts of the region. The work of earlier ice-sheets in this region is not distinctly recorded.

It appears from the foregoing that the present surface of the region is due primarily to the deposition of drift by the last ice-sheet which covered the region. Since the ice melted, the surface has been slightly modified by the streams, which have cleared out and deepened their valleys to some slight extent.

Fig. A. A terrace in the valley of Farm creek.

Fig. B. An alluvial fan near Henry. The velocity of temporary, wet-weather streams is reduced as they leave the gully in the background, and they are forced to deposit the sediment which they carry.

# MIDDLE PORTION OF THE ILLINOIS VALLEY.*

(By Harlan H. Barrows.)

The more important general features of the region adjacent to the middle course of the Illinois are the following: 1. A flattish upland plain, deeply dissected by small valleys in the vicinity of the Illinois, and traversed by morainic ridges. 2. A great valley of very irregular width, lying 150 to 250 feet below the upland plain. 3. An aggrading river (a river which is filling its valley) of extremely gentle fall, which flows sluggishly around the deposits at the debouchures (mouths) of its tributaries. The obstructions made by the deposits of the tributaries cause the main river to expand locally to the dimensions of a lake. 4. An extensive flood plain whose marshes and lakes withhold large areas from agriculture. The flood plain rises very slightly near the banks of the river, making imperfect levees, and also along the bluffs, where it is built up by the deposits of tributary streams, and by slope wash. 5. A remarkable series of alluvial fans, by which the tributaries assist in filling the Illinois valley. 6. A system of sand and gravel terraces, the surfaces of which are uneven locally, because of dunes. The terraces have determined in large part the location of the villages and cities of the region.

*Alluvial Fans*—Nearly every stream tributary to the Illinois in this part of its course has made a deposit of gravel, sand, etc., at its entrance into the valley of the Illinois. These deposits are called alluvial fans (Fig. B, Plate 2) because they are composed of alluvial matter, and because the deposit made by each tributary stream is rudely fan-shaped (semi-circular) in ground plan when normally developed. Generally speaking, alluvial fans are most conspicuously developed at the bases of steep slopes in arid regions, as where streams of diminishing volume leave the relatively high gradients of their mountain valleys to enter lowlands. Their extensive development along the middle Illinois in a humid region of relatively slight relief, is one of the peculiarities of this remarkable valley. This pronounced development of alluvial fans here is the result of the peculiar history of this valley. It formerly served as the outlet for most of the Great

*From an educational bulletin in preparation.

Lakes, the water entering the valley by the route now followed by the Drainage Canal waters. The volume of the outlet river was far greater than that of the present stream. Its great volume gave it great velocity, and it cut its channel down to a very low slope, at a level considerably below that of the present river. Later, when the Great Lakes secured another and lower outlet, the Illinois valley was left with the present relatively small stream, which is unable to wash forward on the gentle grade inherited from its vigorous predecessor, the sediment brought down by its tributaries. This material is accordingly deposited at the mouths of the tributary valleys, forming extensive fans.

The small fans east of Lake Peoria and in other sections of the valley, occasion many of the unevennesses of the roads at the foot of the bluff, and since the fans are higher than the adjacent bottoms, they have frequently been selected as sites for homes. The larger tributaries, such as Farm creek, Ten Mile creek, etc., have built extensive fans of very gentle slope. The fan of Farm creek, opposite Peoria, affords an abundance of land favorably situated for the growing manufactures of the city.

The fans of the larger tributaries divide the bottom lands into more or less distinct sections, and as they are obstructions to drainage, help to maintain the marshiness of the lower tracts lying between them. Furthermore, these deposits determine the position of the Illinois river on its flood plain in many places. Thus the deposits of Bureau creek force the river against the Hennepin bank. Those of Sandy creek, flowing from the east, help to crowd it over to the western edge of the flood plain at Henry. The tributaries opposite Chillicothe accomplish a similar result. The large fan of Ten Mile creek crowds the river against the western bluff at the "Narrows" north of Peoria, scarcely leaving room for the wagon road and railroad which run north from the city, at the base of the bluff. The fan of Farm creek is responsible for the position of the river along the western side of its flood plain at Peoria, while the deposits of Kickapoo creek just to the south divert the stream to the eastern side of the valley at Wesley. The deposits of Lamarsh creek and Mackinaw river control its course farther south, pushing it, in each case, toward the opposite side of the flood plain. The helpless manner in which the river wanders around the deposits of its tributaries was commented upon some years ago by L. E. Cooley of the Chicago Drainage Commission, who pointed out that it was found on the side of the valley opposite the tributary whence the deposits came.

Again, the deposits of certain tributaries greatly affect the width of the Illinois river. The fan of Farm creek acts as a dam, producing the expansion of the river known as Lake Peoria. The type illustration of this class of lakes has been Lake Pepin, produced in a similar manner by a tributary of the upper Mississippi. Above the "Narrows,"

at the fan of Ten Mile creek, is another broad expanse, a mile and three-quarters wide at one point, locally called the Upper Lake. Above the fan of Ten Mile creek, the river has several times its ordinary width nearly to Chillicothe.

The very low slope of the Illinois flood plain, together with the flattish fans of the larger tributaries, accounts for the unusual course taken by some of the streams after they enter the main valley. On entering the valleys of main streams, tributaries commonly flow for a distance down-valley, before joining their mains, with which they usually form acute angles up-stream. In opposition to this general rule, some of the larger tributaries of this district take very irregular courses within the main valley, some of them even flowing some little distance up-valley before joining the master river.

*Terraces*—In common with certain other valleys of the northern part of the United States, the lower Illinois is characterized by a series of extensive flats at varying heights above the flood plain. These flats at varying heights above the flood plain are terraces. (Fig. 3; Fig. A, Plate 2; Plate 3.)

The terraces are composed principally of sand and gravel of varying degrees of coarseness. Both their composition and their structure may be seen at various sand and gravel pits. The material is in layers, and therefore water-laid. Layers of finer and coarser material alternate frequently, and therefore the velocity of the depositing waters changed often at a given place. Traced horizontally, layers thin out and give place to others of different composition; hence the character

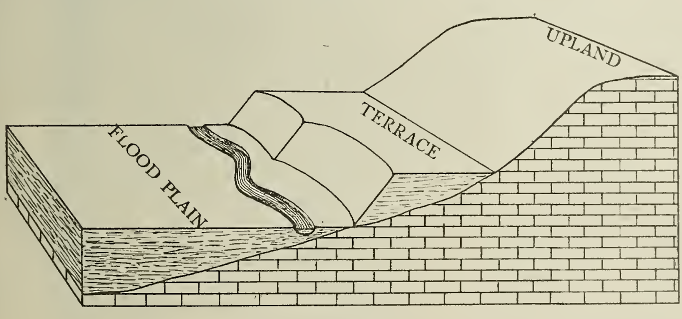


FIG. 3. Diagram showing a terrace along the side of a valley, and its relations to the flood plain below and the uplands above.

of the sediment carried by the depositing waters varied from point to point at a given time. The thin division within layers (laminæ) slant in various directions, and meet each other at varying angles; hence the material was deposited upon an uneven bottom by irregular currents. The deposits of the present flood plain have the same structure as these terrace beds, and are forming under conditions similar to those under which the material of the terraces was deposited. We therefore conclude that the terrace beds are those of ancient flood plains, and that the surfaces of the terraces are parts of old flood plains. Since the terraces are remnants of old flood plains, they are

remnants of flats which originally extended across the valley, to the edge of some higher terrace or to the valley wall. The highest terraces are remnants of the oldest flood plain, and the lower terraces are remnants of successively younger flood plains. Since flood plains decline down-stream, remnants of a given terrace stand at progressively lower levels down-stream.

The terraces are in striking contrast with the present flood plain, in that they are in many places made uneven (1) by sand hills built from them, and (2) by shallow, steep sided valleys cut into them. Sand hills are especially developed on the terraces at Chillicothe and Pekin. At these places they form a complex of irregularly shaped hills and short ridges, often associated with shallow depressions without outlet. In some instances the hills attain heights 30 to 40 feet above their immediate surroundings, and rarely even more. Since the terraces were originally flood-plains, and therefore nearly flat, these sand hills were obviously developed after the flood plain was formed. The hills are dunes, that is, hills of sand, piled up by the wind.

Gravel from the terraces is extensively used on wagon roads and for railroad ballast. The Santa Fe Railway Company ships gravel from its large pit at Chillicothe to all points along its road from the vicinity of Chicago to western Missouri. There are railroad pits also at or near Bureau, Hennepin, Henry and Pekin. Since central Illinois has but limited supplies of good road material, these terrace gravels are likely to find a wide market in the future.

The terrace soils are generally sandy loams, though clay soils are not wanting, especially near the bluffs where there has been more or less wash from the uplands since the terrace material was deposited. Corn is the staple crop of these "sand prairies," as they are called locally. On the terrace south of Spring Bay, large quantities of melons are grown for the Peoria market.

Every important town of this part of the valley grew up upon a terrace, avoiding alike the bottoms, subject to floods, and the uplands, usually 150 or more feet above the waterway. The early relations of the villages to the river are reflected in the fact that the streets in the older quarters run parallel to the river front, and at right angles to it, rather than with the points of the compass. The immediate location of the village upon the edge of the terrace was in several cases determined by relatively large tributary streams on the opposite side of the valley, the deposits of the tributary crowding the river against the terrace at the side of its flood plain. Pekin and Peoria appear to be striking illustrations of this control. Peoria developed back from the lower terraces to a higher one and is now spreading back upon the upland.

Fig. 4. A terrace of the Illinois river, north of Peoria. The slope in the distance is the side of the valley. The bench below the slope, and between it and the river, is part of a broad terrace. (Photo by Dewein.)

# THE SALEM LIMESTONE.

(By Stuart Weller.)

## Contents.

## INTRODUCTION.

The "Bedford limestone" of Indiana is one of the best known and most widely used building stones in the United States at the present time. The distribution of this limestone in Indiana has been shown by Hopkins and Siebenthal,* in the reports of the Geological Survey of that state, and the same authors have described the occurrence and characteristics of the stone, and the methods of conducting the quarrying operations. In their report these authors have used the trade name "Bedford" as the name of the entire formation which is called the Bedford limestone, but this useage is apparently ill-advised because of the prior use of the name Bedford for a formation in Ohio at the base of the Mississippian.† Cumings has proposed the name Salem limestone‡ as a substitute for the Bedford limestone of Hopkins and Siebenthal, and that name is adopted in the present paper. Ulrich has rejected both the names Bedford and Salem, and uses the name Spergen limestone§ for the formation, but the substitution of Spergen for Salem seems to be wholly unwarranted.

The fauna of the Salem limestone has long been a notable one in the literature of American paleontology, because of the remarkable condition of preservation of the fossils in certain of the Indiana localities, and because of the great numbers of individuals. The fauna was first described by Hall, chiefly from material collected at Spergen Hill and Bloomington, Indiana,‖ but without illustrations, the beds furnishing the fossils being referred to the Warsaw limestone of the Mississippi river section. At a later date Whitfield¶ republished Hall's original descriptions of these Indiana fossils with additional notes, accompanied by illustrations drawn from the original type specimens. Still later Hall republished his original paper with additional notes, accompanying the paper by the same plates of illustrations which were published by Whitfield.** These three papers gave to this fauna such notoriety that it has been commonly spoken of as the Spergen Hill fauna, and had not Cumings previously used the name Salem, Ulrich's name, Spergen limestone, would have been highly appropriate as a name for the formation.

*The Bedford Oolitic Limestone, by T. C. Hopkins and C. E. Siebenthal, 21st Ann. Rep Ind. State Geol. pp. 289-427 (1896).

†For a discussion of the usage of the name Bedford see remarks by Cumings, Siebenthal, Chamberlin and Prosser, Jour. Geol., vol. 9, pp. 232-235. 267-271; also Revised Nomenclature of the Ohio Geological Formations, by Charles S. Prosser, Geol. Surv. Ohio, 4th ser., Bull. No. 7, pp. 19-20.

‡Jour. Geol., vol. 9, p. 233, (1901.)

§The Lead Zinc and Fluorspar Deposits of Western Kentucky, by E. O. Ulrich and W. S. Tangier Smith, U. S. G. S., Prof. Pap., No. 36, pp. 28-30, (1905.)

‖ Trans. Albany Inst., vol. 4, pp. 2-36 (1856).

¶ Bull. Am. Mus. Nat. Hist., vol. 1, pp. 39-97, plates 6-9 (1882).

**12th Ann. Rep. Ind. State Geol., pp. 319-375, plates 29-32 (1883).

A peculiar feature of the Spergen Hill fauna as it was described by Hall and by Whitfield, is the diminutive form of most of the species, but further investigation of the fauna in other localities has shown that many of them often attain larger and more nearly normal proportions, and that many of the forms have a wide geographic distribution. In connection with these later investigations, many additional species have been recognized in the fauna, which have been described by various authors in various places, and have usually been recorded as from either the Warsaw or the St. Louis limestone. The latest contribution to our knowledge of this fauna is a paper entitled "The Fauna of the Salem Limestone of Indiana,"* which has been contributed to by E. R. Cumings, J. W. Beede, E. B. Branson and E. A. Smith. In this paper an attempt has been made to gather together in one place, all information available concerning the fauna as it occurs in Indiana.

In the present paper the occurrence of this formation in Illinois will be discussed. Its relations to the other formations of the Mississippian series will be considered, as well as its general physical characters, its geographic distribution, and its possible utilization as a building stone. No attempt will be made to describe in detail the fauna as it occurs in Illinois, but as complete lists of species as can be made at the present time, will be given in an appendix, for the various localities from which fossils have been collected.

## Relation of the Salem Limestone to the Warsaw Formation of Hall.

It has long been recognized that certain limestone beds in Illinois contain representatives of the Spergen Hill fauna of Indiana, indeed, one locality above Alton was frequently mentioned by Hall in his record of the geographic distribution of the species in the original description of the fauna. This locality was referred by Hall to the Warsaw limestone formation, as were also the beds in Indiana bearing the Spergen Hill fauna.

The typical section of the Warsaw limestone, at Warsaw, Hancock county, Illinois, as given by Hall, is as follows:†

| | | Feet. |
|---|---|---|
| 3. | Coarse calcareous yellow sandstone, in thick heavy beds, quarried for building. | |
| 2. | Argillaceous limestone with shaly partings, containing abundance of large Archimedes and other bryozoa; thickness at Warsaw....... | 25 |
| 1. | Magnesian limestone of variable thickness, and sometimes absent. | |

Worthen did not recognize the Warsaw limestone as a distinct major division of the Mississippian in Illinois, but included all the beds so designated by Hall in the "St. Louis Group," extending this interpretation to the limestone beds above Alton and to those at Spergen Hill

* 30th Ann. Rep. Ind. State Geol., pp. 1187-1486, plates 7-47 (1906).
† Geol. Surv., Iowa, vol. 1, pt. 1, p. 161.

and Bloomington, Indiana.* In his report on Hancock county, Worthen has as usual considered the beds comprising the typical Warsaw formation of Hall as a part of the St. Louis limestone and has given the following section of the beds as exposed at the typical locality.†

| | | Feet. |
|---|---|---|
| 4. | Concretionary and brecciated limestone | 10-30 |
| 3. | Calcareous grit stone | 10 |
| 2. | Blue shales and Archimedes limestone | 20 |
| 1. | Magnesian limestone | 8-12 |

The beds 1, 2 and 3 in Worthen's section are identical with those given the same numbers in Hall's section; No. 4 of Worthen's section being the only bed at this point included in the St. Louis by Hall. In Worthen's section the thickness of beds 1 and 3 are mentioned, giving to the entire Warsaw formation of Hall a thickness of something over 40 feet. Hall mentions the thickness of the median member of his formation only, and he considers this bed to be the typical expression of his formation, faunally and physically, and in his table of formations‡ he would apparently restrict the name "Warsaw limestone" to this median bed alone, and correlate with it the limestone above Alton and the beds at Spergen Hill and Bloomington, Indiana.

In a study of the Warsaw locality by the writer the following section, which agrees essentially with those published by both Hall and Worthen, although worked out in greater detail, was carefully measured along the creek east of the town.

| | | Feet. |
|---|---|---|
| 11. | Dense, bluish, brecciated limestone | 10 |
| 10. | More or less cross-bedded limestone, yellow on weathered surfaces and granular in appearance, containing large numbers of broken bryozoans; sometimes replaced by a calcareous grit or sandstone | 8 |
| 9. | Thin-bedded bluish limestone, interbedded with calcareous shales. Fossil bryozoans abundant, especially *Lioclema punctata* and *Archimedes wortheni* | 18 |
| 8. | Fine blue shale | 3 |
| 7. | Hard, light-colored limestone, with few poorly preserved fossils | 4 |
| 6. | Fine blue shale | 8 |
| 5. | Magnesian limestone with shaly bands. Fossils poorly preserved, usually rare, mostly bryozoans | 8 |
| 4. | Bluish shales with numerous geodes which are usually smaller than those in the magnesian limestone beds below | 21 |
| 3. | Magnesian limestone with chert bands | 3 |
| 2. | Magnesian limestone with numerous geodes. Some beds more or less shaly. Geodes most numerous in the middle part of the bed. Fossils poorly preserved and rather rare, mostly imperfect bryozoans | 15 |
| 1. | Blue or grey crystalline limestone with many fossils. Thickness not known, the bed extending below river level (exposed) | 15 |

In this section beds 5 to 10 inclusive comprise the original Warsaw formation of Hall, Bed No. 9 being the typical Warsaw limestone of that author, containing the large numbers *Archimedes* and other bryozoans. Bed No. 10 is the calcareous grit stone, No. 3, of both the

* Geol. Surv. Ill. vol. 1, pp. 83-84; also Econ. Geol. Ill. vol. 1, p. 65.
† Geol. Surv. Ill. vol. 1, p. 333; also Econ. Geol. Ill., vol. 1, pp. 270-71.
‡ Geol. Surv. Iowa, vol 1, pt. 1, p. 109.

Hall section and the Worthen section. This bed is exceedingly variable in character, being at times a nearly pure, cross-bedded limestone, as at the quarry back of the school building at Warsaw, again it is a sandstone or a calcareous grit stone. Hall mentions the occurrence of small quartz pebbles in some places. When the formation is calcareous the weathered surfaces exhibit great numbers of broken bryozoans, more or less imperfectly preserved, and a few brachiopods. The fauna from the quarry near the school house, already mentioned, is as follows:

*Rhipidomella dubia* (Hall).
*Spirifer subaequalis* (Hall).
*Fenestella serratula* (Ulr).
*Fenestella multispinosa* (Ulr).
*Rhombopora* (sp).
*Cystodictya lineata* (Ulr).
*Worthenopora spinosa* (Ulr).

The fauna is notable for the entire absence of *Archimedes, Glyptopora* and *Lioclema,* genera which are most conspicuous in the fauna of the subjacent thin-bedded limestones and shales. On the other hand, all the species recognized here occur commonly and are usually among the more abundant in the limestones further south, near Alton and elsewhere, which Hall considered as representative of his Warsaw limestone. Some or all of the species also occur more or less sparingly in the subjacent bed associated with the abundantly represented genera mentioned above. It is evident, therefore, that although this uppermost member of the Warsaw, as defined by Hall, is somewhat closely related, faunally, to the subjacent and more typical member of the Warsaw group, it is this upper member rather than the typical *Archimedes* and *Lioclema* bearing bed which is to be correlated with the so-called Warsaw limestone above Alton and elsewhere. Like the fauna of this bed at Warsaw, so the fauna of the limestone farther south is notable for the extreme rarity and usually by the entire absence of members of the genera *Archimedes, Glyptopora* and *Lioclema,* and with the possible exception of *Lioclema,* the species of these genera which do rarely occur are usually if not always distinct from those of the *Archimedes* bearing bed at Warsaw.

The locality in the region to the south of Warsaw where the beds under discussion are best exhibited for study is not above Alton, although that is one of the best fossil localities, but is in Missouri, in the neighborhood of Meramec Highlands west of St. Louis. The following section at this locality is compiled from several carefully measured sections in the bluffs of the Meramec river and up the tributary valley to the large quarry by the Frisco Railroad track east of the Meramec Highlands station:

| | | Feet. |
|---|---|---|
| 17. | Grey, granular or compact limestone, the successive beds more or less variable in character, with numerous horizontal chert bands. Fossils rare. The top of this limestone extends to the crusher plant at the quarry, by the railroad track | 40 |
| 16. | Massive, granular, gray limestone with few fossils | 10 |
| 15. | Shaly magnesian beds | 2 |

| | | |
|---|---|---|
| 14. | Limestone filled with fossils of the Spergen Hill fauna............ | 5 |
| 13. | Limestone, somewhat shaly and magnesian in places............... | 7 |
| 12. | Fossiliferous limestone with typical Spergen Hill fauna............ | 2 |
| 11. | Limestone, similar to that above............................... | 4 |
| 10. | Yellowish limestone filled with examples of a Rhynchonelloid shell.. | 2-6 |
| 9. | Limestone beds, often yellowish in color, some beds shaley and apparently somewhat magnesian, other beds filled with bryozoans and other fossils............................................ | 30 |
| 8. | No outcrops, talus probably underlain by shale in the lower part and limestone above........................................ | 26 |
| 7. | Shale exposed................................................. | 2 |
| 6. | No outcrops, probably shale..................................... | 13 |
| 5. | Blue shale, fossiliferous, *Lioclema punctata*, one of the most conspicuous species............................................ | 4 |
| 4. | Blue crystalline limestone with many *Spirifers* at top............. | 4 |
| 3. | No outcrops, probably shales in large part........................ | 18 |
| 2. | Shaly beds with intercalated cherty limestones.................... | 9 |
| 1. | Blue or gray, more or less crystalline limestone, with much chert... | 29 |

In this section three rather well defined divisions may be recognized. The first division includes Beds No. 1 and No. 2 and is well exposed along the base of the bluff to the south of Meramec highlands. It consists of extremely cherty limestones which are free from shale partings below but with more and more conspicuous shale partings and beds above. These beds are exposed to the extent of 38 feet in the measured section recorded above, but all these beds rise to the north and near the abrupt bend in the river some 60 feet are exposed.

The second, next higher division consists largely of shales or shaly limestone as is evidenced by the nearly complete talus covering. Only occasionally, where small ravines have been cut into the bluff, are the beds exposed. No examples of *Archimedes wortheni* have been observed in this bed, but *Lioclema punctata* does occur in abundance where fossils have been collected. This talus covered slope between the limestone outcrops below and above, is a conspicuous feature in the bluffs along the river to the south of Meramec high lands. The thickness of this bed is not accurately known since the talus is banked up against the basal part of the superjacent limestone, obscuring the lower beds of that division, but measured from the top of the lower division to the first exposures of the limestone of the upper division, there are 67 feet, which is doubtless too great, the excess possibly being as much as 20 feet.

The third division is best exposed in the quarry already mentioned and comprises beds 9 to 16, inclusive. The basal part of it is also well seen in the upper portion of the river bluffs. The beds of this division are more or less variable in character, some of them being highly fossiliferous, the fauna being the typical Spergen Hill fauna. Some of the beds near the base are not unlike, in their lithologic characters, the calcareous facies of the uppermost division of the Warsaw group in Hancock county, Illinois. These beds are also well exposed in the cuts along the Frisco railroad between Meramec Highlands and Keyes Summit, and again at the tunnels of the Missouri Pacific railroad at Barrett's Station. Bed No. 17, in the general section here described, differs from the subjacent limestone beds in its different lithologic characters, in the almost entire absence of fossils and in the presence of chert; it is in fact the basal portion of the true St. Louis limestone and need not be considered in the present discussion.

In the section above Alton in the Mississippi river bluffs, the conditions are essentially the same as those at Meramec Highlands, although the continuity of the beds from the cherty limestones below with shale partings, through the more shaly beds of the second division to the limestone at the summit is not so well shown because of the erosion of the Piasa creek. In the first exposures in the bluff east of the mouth of Piasa creek near Lock Haven, the uppermost beds of the shaly division are exposed, followed by the limestones bearing the Spergen Hill fauna. These beds with an easterly dip are then more or less continuously exposed in the base of the river bluff to Hopp Hollow above Alton where they pass below the superjacent limestones, their total thickness being from 90 to 100 feet.

In correlating the Meramec Highlands section and that in the Mississippi river bluff above Alton,with the section at Warsaw, the evidence indicates that the uppermost bed in the Warsaw section, the calcareous grit stone of Worthen and of Hall, with a thickness not exceeding 10 feet, increases in thickness to the south until it attains a depth of approximately 100 feet in the neighborhood of Alton and St. Louis. In this respect this bed resembles the typical St. Louis limestone which becomes much attenuated in thickness to the north. The more typical expression of the Warsaw formation of Hall, comprising the blue shales with intercalated thin limestone beds, with the *Archimedes* and *Lioclema* fauna, extends to the south with no great variation in thickness where it is exhibited in the more or less talus covered shaly bed in the Meramec Highlands section. The geode beds of the Warsaw section, usually considered as the upper limit of the Keokuk limestone, are not present in the more southern region, the higher Keokuk beds being represented by the cherty limestones with shale intercalations in the Meramec Highlands section.

The original Warsaw formation of Hall is therefore two-fold in its nature; the upper division being of but subordinate importance in the typical section, but increasing in thickness to the south until it entirely overshadows the lower and more typical beds. In making such a division of the original formation the name Warsaw may be restricted to the lower, more typical part which includes much the larger portion of the beds in the type section. The upper division, as it is followed to the south from Warsaw, becomes an important limestone formation which is everywhere characterized by the Spergen Hill fauna of Indiana, and may be definitely correlated with the Salem limestone of that state.

The dual nature of the beds referred to the Warsaw formation by various authors was recognized by Williams*, although he was unable to straighten out the confusion from a study of the literature alone. Keyes† also recognized the same fact and united all the beds of Hall's original section with the Keokuk, while the so-called Warsaw limestones above Alton and elsewhere were considered as forming the basal portion of the St. Louis limestone. He failed to recognize the

* Bull. U. S. G. S. No. 80, p. 169 (1891).
† Iowa G. S., vol. 1, pp. 70-71 (1893).

fact, however, that these limestone to the south were really the more expanded extension of the subordinate upper member of the Warsaw formation in its typical section.

### RELATIONSHIP OF SALEM LIMESTONE TO ST. LOUIS LIMESTONE.

The name St. Louis limestone was first applied by Englemann* to the limestones which underlie "the western edge of the great Illinois coal filed." The definition of the formation was inadequate according to recent standards, and the stratigraphic relations of the beds were misunderstood since the formation was supposed to overlie those beds which we now call Cypress sandstone and Chester instead of being subjacent to them as is now known to be the case.

In the 1855 Report of the Geological Survey of Missouri, both Swallow. and Shumard discuss the St. Louis limestone, and both are in accord in their interpretation of the formation. The best exposition of the conception of this limestone formation held by these men is given in Shumard's report on St. Louis County,† in the description of the geologic section along the line of the Pacific Railroad, now the Missouri Pacific Railroad. In this description the beds exposed at both tunnels at Barrett's Station, which beds are referred to the Salem limestone in this paper, are distinctly described as belonging to the "Archimedes limestone," a formation subjacent to the St. Louis limestone, and this relation is clearly shown in the graphic section accompanying the report. In the description of the Archimedes limestone by Swallow‡ the strata on the Des Moines river and near Keokuk, Iowa, are mentioned in such a manner as to show clearly that his Archimedes limestone is considered as essentially the equivalent of the beds called Warsaw by Hall at a later date. It is clear then that these authors who were the first to define the St. Louis limestone in a manner at all adequate excluded from that formation these beds which we call Salem limestone.

Hall's interpretation of these beds has already been discussed. He followed essentially the interpretation of Swallow and Shumard, and considered this formation as distinct from the St. Louis limestone, calling it the Warsaw limestone.

Worthen departed from the interpretation of these earlier geologists and considered the beds under discussion as a part of his St. Louis group,§ and included also under this head the typical Warsaw limestone of Hancock county. It is clear, however, that Worthen did not intend to completely dispense with the name Warsaw as a formation name as he not infrequently mentioned the Warsaw division of the St. Louis in his county reports, but he at no time distinguished between the typical Warsaw as that formation would be restricted by the writer and the higher division here called the Salem limestone. Worthen's usage of St. Louis as a group name in which was included a

* Am. Jour. Sci. 2nd Ser.; vol. 3, p. 119 (1847).
†1st and 2nd Ann. Rep. Geol. Surv., Mo., pt. 2, p. 169, (1855.)
‡Loc. cit., pt. 1, p. 95.
§Geol. Surv. Ill., vol. 1, p. 83 (1866); also Econ. Geol. Ill., vol. 1, p. 65, (1882.)

subordinate division, the St. Louis limestone proper, has led to some confusion among more recent authors, and the more general conception of late years has been that the St. Louis limestone in its original definition included all these limestones under consideration.

Extended field observations by the writer have shown that the Salem limestone is as clearly defined a stratigraphic unit in the Mississippian series of the Mississippi valley as any of the formations recognized. The formation may be easily distinguished from the superjacent St. Louis limestone on lithologic characters alone, and when the faunal characters are considered the difference is even more striking. The formation includes beds of more or less variable lithologic characters, the variable character being perhaps more pronounced in the northern than in the southern outcrops. Usually the formation is nearly or quite free from chert. Throughout its extent it contains important beds of light-colored, nearly white limestones, which are not infrequently more or less oolithic in texture. In some cases the apparent oolithic grains are the shells of a small foramifera *Endothyra bailey,* but again there are true oolites. These lighter colored beds have a peculiar method of weathering which is not often observed in any other of the Mississippian formations. The more or less vertical faces of the outcrops scale off in a transverse direction to the bedding in rather thin, irregular flakes from three to six inches across and an inch or less in thickness, this fracturing of the rock evidently being due to frost action. Fine grained, bluish grey or buff colored magnesian beds of varying thickness are not infrequently interbedded with the more nearly pure limestones, and at two localities, one in Madison county and the other in St. Clair county, beds of this character have been extensively mined for the manufacture of hydraulic cement, although the deposits have not been worked during recent years.

The purer limestones in this formation are usually more or less abundantly fossiliferous, and the fossils often occur in an excellent state of preservation. Among the most conspicuous forms are the bryozoans, belonging to the genera *Fenestela, Polypora* and *Crystodictya,* which often present a nearly pure white color in the slightly darker matrix.

The Salem limestone does not contain, at least as a conspicuous element, beds of dense, compact, bluish gray limestones with conchoidal fracture and with a texture almost of lithographic stone, such as are commonly present in the St. Louis limestone; neither are there present the brecciated beds which are so characteristic of the St. Louis. The two formations may also be differentiated by reason of the abundance of fossils in the Salem and the comparative rarity of them in the St. Louis, at least in such a condition of preservation as to be readily determined. In fact, most of the so-called St. Louis fossils in the Mississippi valley are in reality from the Salem limestone.

Although there is no structural break between the Salem and the St. Louis, and the sedimentation was evidently continuous from the lower to the upper formation, except in the extreme northern extension of the beds where there is a possible slight uniformity, the dividing line between the two formations in any given section may usually be

easily recognized within a thickness of from five to ten feet. This separation may ordinarily be made on the lithographic characters alone, but with the aid of the fossils no mistake can be made.

### THE MERAMEC GROUP OF ULRICH.

Ulrich has defined as the Meramec group* those beds included in the St. Louis group of Worthen, the name Meramec being substituted for St. Louis in order to avoid the usage of that name in two senses. In this group he includes the Warsaw, Spergen and St. Louis. The Warsaw formation, however, should from both physical and faunal reasons be more properly joined with the subjacent Keokuk formation, which would bring it into the Osage group, and there is no more reason for associating the Salem and the St. Louis in one larger division than in bringing the St. Louis and the superjacent St. Genevieve formations together. It would seem, therefore, that in so far as the Illinois stratigraphy is involved the recognition of a Meramec group is of doubtful utility.

### GEOGRAPHIC DISTRIBUTION OF SALEM LIMESTONE IN ILLINOIS.

*Hancock county*—As has already been indicated, the northermost point where the Salem limestone has been recognized is at Warsaw, in Hancock county, where the formation is represented by a bed of grit, or arenaceous limestone of variable lithologic character, which reaches a thickness of only eight to ten feet. There is no clearly defined unconformity at this locality upon the subjacent Warsaw limestone and shale, but the presence of the arenaceous beds which sometimes, according to Hall, contain quartz pebbles, is at least suggestive of an unconformity. The unconformity, however, if such be present, is only a slight one, since a numberof species of fossils are common to the Warsaw formation and the superjacent Salem limestone. The species of fossils which have been identified in the Salem limestone of Hancock county have already been mentioned.

*McDonough, Schuyler, Adams, Brown, Pike, Greene and Jersey counties*—In these counties no examination of the Salem limestone has been made by the writer except in Adams and Calhoun. In all of them, however, the St. Louis limestone is described by Worthen,† and from reading his descriptions one can usually recognize certain of the lower beds which should doubtless be referred to the Salem limestone. In Adams county, where the formation has been seen, but not carefully studied the beds are similar in character to the equivalent beds further south. In Calhoun county the Salem limestone occurs

*U. S. G. S., Prof. pap. No. 36, pp. 28-34.

†McDonough Co., Geol. Surv. Ill., vol. 5, p. 260; also Econ. Geol. of Ill. vol. 3, p. 273. Schuyler Co., Geol. Surv. Ill. vol. 4, p. 84; also Econ. Geol., vol. 2, p. 330. Adams Co., Geol. Surv. Ill. vol. 4, pp. 51-53; also Econ. Geol. Ill., vol. 2, pp. 293-396. Brown Co. Geol. Surv. Ill., vol. 4, pp. 68-69; also Econ. Geol. Ill., vol. 2, pp. 313-314. Pike Co., Geol. Surv. Ill., vol. 4, p. 32; also Econ. Geol. Ill., vol. 2, p. 272. Calhoun Co., Geol., Surv. Ill., vol. 4, p. 15; also Econ. Geol. Ill., vol. 2, p. 253. Greene Co., Geol. Surv. Ill., vol. 3, pp 127-128; also Econ. Geol. Ill., vol. 2, pp. 51-52. Jersey Co., Geol. Surv. Ill., vol. 3, pp. 111-112; also Econ. Geol. Ill., vol. 2, pp. 32-33.

in only a single limited area adjacent to the Cap au Grés fault. The exposures are much weathered and appear to be porus, brown, magnesian limestone in which the fossils are imperfectly preserved.*

In passing southward from Hancock county the formation becomes thicker, but does not attain its normal thickness of nearly 100 feet until Madison county is reached.

*Madison county*—In Madison county the Salem limestone is exposed in the Mississippi river bluffs from near the mouth of Piasa creek to Hopp Hollow, two miles above Alton. In the bluffs ¼ mile below the mouth of Piasa creek the lower beds of the formation are exposed resting upon the subjacent Warsaw shales. In passing down the river higher and higher beds are exposed by reason of the gentle dip of the rocks to the east, until, at Hopp Hollow, the formation passes beneath the surface. A series of measured sections have been studied in these bluffs, which give the total thickness of the formation as 94 feet.

The first of these sections is ¼ of a mile east of the Piasa creek, above the tracks of the C. P. & St. L. Railroad, in which the following beds were recognized.

| | | Feet. |
|---|---|---|
| 13 | Thin bedded limestone, very fine in texture, of grey or yellowish color; beds ⅛ to 1 inch in thickness, almost shale-like in ap pearance, 93-100 feet. | 7 |
| 12 | Talus covered slope. 79-93 feet | 14 |
| 11 | Limestone of variable character, apparently more or less magnesian, some beds more magnesian than others. Mostly rather thin bedded, but some beds 1 foot in thickness. Partially covered with talus. 69-79 feet | 10 |
| 10 | Gray or buff limestone, granular in texture, heavy bedded, with scaly weathered surface. Fossils abundant. (W93). 58-69 feet | 11 |
| 9 | Fine grained, gray or blue magnesian bed, similar in texture to the cement bed formerly mined near Clifton. 56-58 feet | 2 |
| 8 | Limestone with coarse, irregular texture, with numerous crinoid stems and bryozoans showing on the weathered surface. 55-56 feet | 1 |
| 7 | Yellowish, impure magnesium limestone. 54-55 | 1 |
| 6 | Fine grained granular limestone, gray or yellowish in color. Good fossils not common although the entire bed is composed of worn organic fragments. 42-54 feet | 12 |
| 5 | Impure, brownish limestone, more or less thin bedded. 39-42 feet | 3 |
| 4 | Yellowish, granular, crystalline limestone, with abundant fossils, some of which are well preserved. (W92). 34½-39 feet | 4½ |
| 3 | Limestone similar to that above but with the fossils less perfectly preserved. This bed is in two ledges with a shaly band between. 28-34½ feet | 6½ |
| 2 | Talus slope with no exposure. 3-28 feet | 25 |
| 1 | Blue shale exposed a few rods above the point where the re mainder of the section was measured. 0-3 feet | 3 |

In this section bed No. 1 is doubtless a part of the shaly Warsaw formation, although no fossils were secured. The talus slope between 3 and 28 feet is probably in large part underlain by the Warsaw shales, although the basal part of the superjacent Salem limestone may also be covered. Beds Nos. 3 to 13 are all to be included in the Salem limestone.

‡Bull. Ill. State Geol. Surv., No. 4, p. 228.

The next section in the series is in the bluff above Riehl's Statio, on the C., P. & St. L. railroad, where the following beds were reco-nized:

| | | Fe |
|---|---|---|
| 9 | Granular, gray limestone, with scaly weathering, thinner bedded above, the weathered surface covered with fragmentary crinoid stems and other fossils. 54-65 feet | 11 |
| 8 | Oolitic limestone filled with fossils (W95). 52-54 feet | 2 |
| 7 | Dense, more or less irregularly bedded limestone, apparently somewhat magnesian. 47-52 feet | 5 |
| 6 | Granular, gray or yellowish limestone exhibiting scaly weathering. 37-47 feet | 10 |
| 5 | Heavy bedded limestone with many fossils. 26½-37 feet | 10 |
| 4 | Limestone which is apparently in part magnesian. Fossil bryozoans. 24½-26½ feet | 2 |
| 3 | Heavy ledge of limestone which is probably the same as bed No. 3 in the last section. 20-24½ feet | 4 |
| 2 | Limestone, variable in character with a one foot fossil band at elevation 12-13 feet (W94). 10-20 feet | 10 |
| 2 | Blue, gritty shales, similar to that at the base of last section. 0-10 feet | 10 |

The shale at the base of this section, bed No. 1, is the same as t shale at the base of the last section and is doubtless a part of t Warsaw formation. The remainder of the section is entirely with the Salem limestone.

Below Riehl's Station these beds are again well exposed, althou the Warsaw shales at the base soon pass below the surface becau of the easterly dip of the strata. A little distance east of the railro trestle below the station a small collection of fossils was made fro No. 4 of the above section where this bed has dropped to a level of abo 16 feet above the railroad track (W96), and another collection fro the same locality from the same limestone just above the last, s inches to one foot in thickness (W97).

The next section in this series starts from the mouth of a sm ravine known as Hull's Hollow about one and one-half miles belo Clifton Terrace station, and was measured to the top of the blu west of the ravine. The beds recognized are as follows:

| | | Fe |
|---|---|---|
| 15 | Heavy, brecciated or conglomeratic limestone. 171-183 feet | 12 |
| 14 | Limestone of variable character, thick and thin beds, some layers apparently magnesian and some layers shaly. 117-171 feet | 54 |
| 13 | Brecciated limestone. 110-117 feet | 7 |
| 12 | Hard, gray limestone with numerous plates and spines of *Archaeocidaris* on the weather surfaces. 102-104 feet | 2 |
| 11 | Hard, gray limestone. 97-102 feet | 5 |
| 10 | Limestone ledges more or less talus covered, some beds shaly. 61-97 feet | 36 |
| 9 | Hard, fossiliferous limestone (W45). 59-61 feet | 2 |
| 8 | Limestone, mostly in heavy beds, with some thinner shaly beds. Fossils not abundant. 38-59 feet | 21 |
| 7 | Buff colored, shaly, magnesian bed. 34-38 feet | 4 |
| 6 | Hard, fine grained, gray limestone exposed in lower part of old quarry. 26-34 feet | 8 |
| 5 | Talus covered. 20-26 feet | 6 |

| | | |
|---|---|---|
| 4 | Gray, fossiliferous limestone forming the lower waterfall near the mouth of the ravine (W44). 10-20 feet | 10 |
| 3 | Hard limestone ledge, oolitic in part, with a large Spergen Hill fauna (W43). 9-10 feet | 1 |
| 2 | Earthy magnesian bed, with texture similar to that of the "cement bed" formerly mined near Clifton. 7-9 feet | 2 |
| 1 | No exposure from river level. 0-7 feet | 7 |

In this section beds Nos. 1-9 may be included in the Salem limestone, the higher beds being a part of the St. Louis limestone. It was probably from beds Nos. 3 and 4 of this section, or from Hopp Hollow, the section next to be described, that Hall's material mentioned as coming from above Alton in his paper on the Spergen Hill fauna of Indiana, was obtained. The oolitic portion of bed No. 3 is especially rich in fossils and contains a large portion of the same species, in a very perfect condition of preservation, as the Spergen Hill and Bloomington beds of Indiana. This bed is also probably the equivalent of bed No. 8 in the Riehl's Station section, where it occurs at an elevation of from 52 to 54 feet above the railroad track.

In the quarry of the Blue Grass Crusher Co., just west of Hopp Hollow, the upper beds of the Salem limestone are exposed with the superjacent St. Louis limestone. The measured section at this point is as follows:

| | | Feet. |
|---|---|---|
| 13 | Brecciated limestone. 130-142 feet | 12 |
| 12 | Gray to buff limestone, becoming somewhat thinner bedded above. 108-130 feet | 22 |
| 11 | Brown limestone. 105½-108 feet | 2½ |
| 10 | Dense gray limestone with numerous sections of brachiopods shown upon the weathered surface. 103½-105½ | 2 |
| 9 | Gray limestone, thin bedded in one inch layers, with occasionally brownish layers. Ripple marked surface at elevation 83. 81-103½ feet | 22½ |
| 8 | Limestone, heavy bedded below, becoming thinner bedded above to top of quarry. 64-81 feet | 17 |
| 7 | Yellow, earthy layer, probably magnesian. 60-64 feet | 4 |
| 6 | Impure limestone in thick and thin beds, some shaly layers, six inches of blue clay shale at the base. Towards the top the beds become thicker, being hard, dense limestone. 47-60 feet | 13 |
| 5 | Impure limestone with much chert, somewhat earthy in texture. Yellowish in color, probably magnisian. 34-47 feet | 13 |
| 4 | Magnesian (?) limestone, shaly below. 31-34 feet | 3 |
| 3 | Dense limestone with some chert. 26-31 feet | 5 |
| 2 | Limestone similar to that below, but more dense, a little darker in color, with some hard masses and some chert. 18-26 feet | 8 |
| 1 | Light gray, granular limestone, with an abundance of fossils in pockets and bands. No chert (W42). 0-18 feet | 18 |

In this section bed No. 1 represents the summit of the Salem limestone, all the higher beds being of the St. Louis limestone. The fauna of this bed is somewhat extensive and is the typical Spergen Hill fauna of Indiana. Below this quarry the Salem quickly passes out of sight by reason of the eastward dip of the strata.

*St. Clair county.*—On the Illinois side of the Mississippi river the outcrop of the Mississippian beds is interrupted between the northern part of Madison county and the southern part of St. Clair, by the broad American bottom, the alluvial deposits extending eastward to

beyond the line separating the Mississippian and the Pennslyvanian series. At the point where the bluffs of Mississipian limestone reappear in southern St. Clair county, the beds exposed are typical St. Louis limestone, with a gentle northerly dip. Following the bluffs to the south the beds arise until the Salem limestone appears in the base of the bluffs and finally constitutes nearly or quite all of the limestone beds exposed in the bluff. Before the Monroe county line is reached, however, the crest of an anticline is passed and the beds again pass beneath the surface. In the point of the hill just northwest of Sugar Loaf school house the St. Louis limestone beds of the southwestern limb of the anticline exhibit a dip of 31 degrees, which is much more abrupt than the dip of the opposite limb.

In the upper part of the ravine extending back from the river at Sugar Loaf school house where the old cement mine is located, a good section is exposed, the base of the section being shown in the bank of the creek back of the house occupied by Mr. James Bergen, and the upper beds at the cement mine.

| | | Feet. |
|---|---|---|
| 13 | Ledges of thick and thin bedded limestones, more or less granular and crystalline in texture, usually light in color with gray or brown tints, some thin beds apparently magnesian and occasionally shaly partings. All these beds are more or less covered with talus. 47-80 feet | 33 |
| 12 | Cement bed. Earthy, bluish or gray magnesian limestone with uniform texture. Exactly similar in texture to the cement bed in the Salem limestone near Clifton Terrace in Madison county. 39-47 feet | 8 |
| 11 | Thin bedded limestones. 36-39 feet | 3 |
| 10 | Thin bedded blue limestone with large numbers of fossil Spirifers (W250). 35-36 feet | 1 |
| 9 | Thin bedded limestone similar to the beds above. 33-35 feet | 2 |
| 8 | Limestone similar to that above with numerous fossils (W249). 32-33 feet | 1 |
| 7 | Thin bedded limestone with bands of shales. 30-32 feet | 2 |
| 6 | Fossiliferous limestone (W248). 29-30 feet | 1 |
| 5 | Buff or blue shales with occasional thin beds or lenses of limestone. 18-29 feet | 11 |
| 4 | Buff colored fossiliferous shales (W247). 16-18 feet | 2 |
| 3 | Buff or blue shales with occasional thin beds or lenses of limestone. 6-16 feet | 10 |
| 2 | Irregularly thin bedded, fossiliferous limestone strata with interbedded shale (W246). 4-6 feet | 2 |
| 1 | Blue and buff fossiliferous shales (W245) 0-4 feet | 4 |

In this section a little over 40 feet of the higher beds including th cement bed are referable to the Salem limestone. The lower bed represent the shaly Warsaw formation as it is so well developed in St Louis county, Missouri, and as it occurs in northern Madison county

*Monroe county*—A quarry in the Salem limestone was formerl worked in the southwest quarter of section 14, about a mile southeas of Columbia. At this point a thickness of about 48 feet of limeston is exposed which is more or less variable in color and texture. It characters agree well with those of the Salem limestone exposed i the river bluffs of southern St. Clair county. In the bed of the quarr is a shaly bed which is abundantly fossiliferous, the fauna being

haracteristic assemblage of the Salem limestone (U 48). At another ocality one and one-half miles south of Columbia, in the southeast quarter of section 27, the Salem limestone is exposed. The rock at his locality is similar in its physical and faunal characters to the beds of similar age further north. Fossils are somewhat abundant (U 56).

At both of the last localities the Salem limestone has been brought o the surface by the anticlinal folding of the beds, exhibited in the iver bluff in southern St. Clair county. In the Mississippi river luffs the Salem limestone is not exposed in Monroe county until a oint south of Fountain creek is reached where the rocks begin to ise to the anticlinal axes exhibited in the outcrop of the Kimmswick imestone at Valmeyer. The outcrops in this portion of the bluff have ot been studied in detail, and no collections have been made, but the bservations which have been made indicate that the characteristics f the formation are not different here from other localities. Immediately south of the Valmeyer anticline, the Salem limestone is not learly shown in the Mississippi river bluffs. All the beds which are xposed where one would expect to find the Salem limestone seem to elong in the St. Louis formation; the Salem is either covered with he talus at the foot of the bluff or the strata have been faulted in such manner as to obscure the beds in question. This region has been xamined only in a hasty manner and a few days detailed work will loubtless make the relations clear.

Below Chalfin Bridge P. O. the Salem limestone again appears in he base of the bluffs, the summit of the formation rising to a height f 59 feet above the bottom lands in the northwest corner of section , a little over one-half mile southeast of the post office. At this oint the following section was carefully measured.

| | | Feet. |
|---|---|---|
| 9 | Hard, blue or gray limestones, more or less variable in texture and variously bedded, having the typical characteristics of the St. Louis limestone. 213-231 feet | 18 |
| 8 | Limestone filled with large and small colonies of the coral Lithostrotion. 198-213 feet. | 15 |
| 7 | Limestones in every way similar to those above the corraline bed. 151-198 feet | 47 |
| 6 | Limestone filled with fossil cephalopods of various genera (W237). 150-151 feet. | 1 |
| 5 | Limestone beds similar to those higher up, passing into an exceedingly hard, dense blue limestone, just beneath the cephalopod layer. 86-150 feet | 64 |
| 4 | Hard, siliceous limestone having almost the appearance of a very hard sandstone. 85-86 feet. | 1 |
| 3 | Beds variable in character, for the most part magnesian, earthy limestones, buff or brown in color, with bluish beds near the top. 59-85 feet | 16 |
| 2 | Light colored, grayish or yellowish limestones, having the features characteristic of the Salem limestone. Fossils common (W236). 30-59 feet | 29 |
| 1 | No exposures to the level of the bottom land. 0-30 feet | 30 |

The Salem limestone is represented by bed No. 2 of this section, ıis being the upper portion of the formation. The higher beds are ll St. Louis limestone.

One mile southeast of the last section, opposite the residence of Mr. William Maeys, the Salem-St. Louis contact is only 25 feet in elevation above the river bottom, the section being as follows:

| | | |
|---|---|---|
| 5 | Thin bedded magnesian limestones. 84-94 feet.................. | 10 |
| 4 | Chert band. 83-84 feet .................................. | 1 |
| 3 | Magnesian limestone, quarry ledge. 77-83 feet.................. | 6 |
| 2 | Thin bedded magnesian limestones. 25-77 feet .................. | 52 |
| 1 | Limestone having the characteristic features of the Salem exposed above, covered with talus below. 0-25 feet .................. | 25 |

From this point the summit of the Salem limestone rises gently and regularly for a distance of a little over three and one-fourth miles, to the ravine which intersects the bluff about one mile below the northwestern boundary of the Renault grant, just south of which the Salem-St. Louis contact occurs at an elevation of 66 feet above the river bottom. Just below this point the continuity of the formation is interrupted by a fault and one-half mile to the southeast the contact is recognized at an elevation of 176 feet.

Continuing along the bluffs, the beds rise gently at first and then more abruptly to an anticlinal axis which intersects the bluff opposite the village of Renault. Over the anticline the Salem limestone beds have been practically removed so that the contact between it and the St. Louis limestone has not been seen, but the base of the Salem, resting upon the subjacent Keokuk-Warsaw formation, may be seen at an elevation of 145 feet in the bluff just below the intersection of the road to Renault with the river road in the northeast quarter of Section 1. Assuming the thickness of the Salem as 100 feet, which is as close as it can be estimated for Monroe county, the Salem-St. Lauis contact would be at an elevation of 245 feet. Continuing to the southeast the beds descend rapidly upon the southern limb of the anticline, the Salem-St. Louis contact having an elevation of 95 feet about one mile from Randolph county line, and 65 feet at a point about one-half mile below. Before reaching the Randolph county line, the formation has passed below the level of the river bottom and is not again exposed until the neighborhood of Grand Tower, in Jackson county, is reached.

Throughout Monroe county wherever the formation occurs, the lithologic expression of the Salem limestone is uniform and it can be easily recognized. It is furthermore characterized throughout by the characteristic Spergen Hill fauna. At some points certain beds of the limestone might be satisfactorily and profitably developed as building stone. The Iron Mountain Railroad, running the entire length of the county between the bluffs and the river would furnish good transportation facilities. The locality where the formation seems to be most favorably situated for quarry purposes is about one mile above the Randolph county line in the point of the bluff west of the road which runs in a northerly direction to the village of Renault. At this point the rock occurs in more than usually heavy beds; it is apparently uniform in texture and color, and resists the action of weathering. Furthermore, it is not covered at this point by heavy ledges of the superjacent St. Louis limestone and a large quarry might be opened with but a minimum amount of stripping. Careful tests would be

necessary to determine whether the rock at this point would be equal for purposes of construction, to the celebrated "Bedford stone" of Indiana, but the superficial examination of the locality would seem to indicate this to be the case.

*Jackson county*—In the vicinity of Grand Tower, in Jackson county, three conspicuous hills rise abruptly above the broad alluvial plain which extends from the Mississippi to the Big Muddy river. The first and largest of these hills is known as "Big Hill" or "Fountain Bluff." This elevation is several miles in length, its southern extremity being two miles north of the town; the constituent rock strata are of Chester age below, passing upward into the Mansfield sandstone and conglomerate of the Pennsylvanian. Just northwest of the town, along the river bank, is the long narrow ridge known as the "Devil's Back Bone," which is entirely of Devonian rocks. Northeast of the town is the third elevation which is much broader and less abrupt than the "Back Bone;" at its southern extremity the rocks are of Devonian age, but at its northern end they are Mississippian limestones. In the extreme northern part of this hill a quarry known as the "City Quarry" has been opened in which the Salem and St. Louis limestones are exposed. The beds at this point dip to the northeast at an angle of about 24 degrees so that the lower strata are exposed in the southwestern part of the quarry. Certain of these lower beds exhibit features which are highly characteristic of the Salem limestone elsewhere, with the typical Spergen Hill fauna represented by an abundance of both species and individuals. The dividing line between the Salem and the St. Louis is not so distinctly shown here as in Monroe county, but the lower beds in the quarry are none the less distinctly Salem limestone.

*Union county*—The stratigraphy of the Mississippian formations in Union county was misinterpreted by Worthen because of his failure to recognize the extensive faulting of the strata which has taken place in the southern part of the State. In the east and west section passing through Jonesboro and Anna he recognized a succession of higher and higher beds passing from the Devonian black shale through the Mississippian series in regular succession, except that the St. Louis limestone was believed to follow immediately after the supposed Kinderhook shales, the limestone along Swan creek, east of Anna, being considered as the upper beds of the St. Louis*. A reconnaissance survey of this part of the State by the writer has shown that the structural features are by no means so simple as Worthen's interpretation would indicate. The succession of the beds is perfectly normal through the Kinderhook, Burlington, Keokuk-Warsaw, Salem and St. Louis, but their relations have been obscured by faulting. A fault with a general north-south direction seems to pass along Swan creek with the upthrow on the east, so that the supposed upper St. Louis beds of Worthen appear to be the Salem limestone. The fauna of the limestone exposed in the old quarries along Swan creek is nearly the typical Spergen Hill fauna, and this occurrence of the fauna in beds supposed to be upper St. Louis is perhaps one of the facts which led Worthen to combine the Salem and St. Louis limestones in one formation. The

*Geol. Surv., Ill., vol. 3, pp. 41-44; also Econ. Geol. Ill., vol. 1, pp. 483-487.

fauna at this locality has some features, however, which suggest that it is a representative of the recurrent Spergen Hill fauna of the Ste. Genevieve limestone lying above the St. Louis. The true relations of the beds in this region can only be determined by more detailed study.

In its lithologic character the supposed Salem limestone of Union county resembles the same formation elsewhere except that some of the beds are more cherty than is usually the case with the formation. The survey of the region has not yet been carried far enough to determine the extent of the formation in the county, and as yet it has only been observed along Swan creek, where it is represented by at least 100 feet of strata.

## CONCLUSION.

The Salem limestone, as has been shown in the preceding pages, is widely distributed in Illinois, from Hancock to Union counties, although the outcrops of the formation are not continuous at the surface through this entire area. Its lithologic characters are more or less uniform throughout the State and it can usually be differentiated from the superjacent St. Louis limestone without difficulty. The faunal characters of the formation are even more uniform than the physical, and are identical with the faunas of the typical expression of the formation in Indiana.. These beds which appear at intervals along the western side of the Illinois coal field, are doubtless continuous beneath it across the entire width of the State and a part of Indiana, coming to the surface again near the eastern border of the coal field in the latter State. In Indiana the formation affords one of the most valuable building stones of America. In Illinois it is apparently not usually so well adapted for such purposes as in Indiana, either because of the physical characters of the rock itself or because of the overlying heavy beds of St. Louis limestone, but at certain localities in Monroe county extensive beds could probably be quarried which would prove to be the equal of the Indiana "Bedford stone" in all respects.

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## APPENDIX.

Preliminary lists of species in the Salem limestone faunules collected in Illinois.

### W. 56. WARSAW, HANCOCK COUNTY. (See p. 85.)

*Rhipidomella dubia* Hall.
*Spirifer subaequalis* Hall.
*Fenestella serratula* Ulr.
*Fenestella multispinosa* Ulr.
*Rhombopora* sp.
*Cystodictya lineata* Ulr.
*Worthenopora spinosa* Ulr.

### W 92. NEAR LOCK HAVEN, MADISON COUNTY. (See p. 91.)

*Fistulipora spergenensis* Rom.
*Rhipidomella dubia* Hall
*Orthothetes minutus* Cum.
*Productus* Sp.
*Spirifer subaequalis* Hall.
*Spirifer lateralis* Hall.
*Seminula trinuclea* Hall.

### W 93. NEAR LOCK HAVEN, MADISON COUNTY. (See p. 91.)

*Endothyra baileyi* Hall.
*Zaphrentis spergenensis* Worthen.
*Zaphrentis* sp.
*Talarocrinus simplex* Shum.
*Stenopora* sp.
*Fenestella serratula* Ulr.
*Hemitrypa prouti* Ulr.
*Hemitrypa beedei* Cum.?
*Cystodictya lineata* Ulr.
*Worthenopora spatulata* (Prout).
*Productus altonensis* N. & P.
*Productus biseriatus* Hall.
*Productus indianensis* Hall.
*Camarophoria subuneata* Hall.
*Dielasma formosa* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subcardiiformis* Hall.

### W 94. RIEHL,S STATION, MADISON COUNTY. (See p. 92.)

*Fistulipora spergenensis* Rom.
*Polypora simulatrix* Ulr.?
*Cystodictya lineata* Ulr.
*Spirifer bifurcatus* Hall.
*Spirifer subaequalis* Hall.
*Spirifer lateralis* Hall.
*Reticularia pseudolineata* Hall.
*Platyceras* sp.

### W 95. RIEHL'S STATION, MADISON COUNTY. (See p. 92.)

*Endothrya baileyi* Hall.
*Zaphrentis spergenensis* Worthen.
*Archaeocidaris* sp.
*Pentremites conoideus* Hall.
*Rhombopora bedfordensis* Cum.?
*Cystodictya lineata* Ulr.
*Worthenopora spatulata* (Prout).
*Orthothetes minutus* Cum.
*Productus biseriatus* Hall.
*Pugnax grosvenori* Hall.
*Dielasma formosa* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subaequalis* Hall.
*Eumetria marcyi* (Shum.)
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Nuclua shumardi* Hall.
*Microdon oblongus* Hall.
*Straparollus spergenensis* Hall.
*Holopea proutana* Hall.
*Cladodus* sp.

### W 96. EAST OF RIEHL'S STATION, MADISON COUNTY. (See p. 92.)

*Monilopora beecheri* Brab.
*Pentremites conoideus* Hall.
*Fistulipora spergenensis* Rom.
*Fenestella tenax* Ulr.
*Orthothetes minutus* Cum.
*Rhipidomella dubia* Hall.
*Spirifer bifurcatus* Hall.
*Reticularia pseudolineata* Hall.
*Cliothyris hirsuta* Hall.

### W 97. EAST AT RIEHL'S STATION, MADISON COUNTY. (See p. 92.)

*Rhipidomella dubia* Hall.
*Productus* sp.
*Spirifer lateralis* Hall.
*Seminula trinculea* Hall.

### W 43. HULL'S HOLLOW, MADISON COUNTY. (See p. 93.)

*Endothyra baileyi* Hall.
*Zaphrentis cassedayi* E. & H.
*Enallophyllum grabaui* Green.
*Pentremites koninckana* Hall.
*Poteriocrinus* sp.
*Talarocrinus simplex* Shum.
*Spirorbis annulatus* Hall.
*Fenestella tenax* Ulr.
*Fenestella exigua* Ulr.
*Hemitrypa proutana* Ulr.
*Hemitrypa nodosa* Ulr.
*Polypora simulatrix* Ulr.
*Polypora varsoviensis* (Prout).
*Glyptopora* sp.
*Orthothetes minutus* Cum.
*Rhipidomella dubia* Hall.
*Productus altonensis* N. & P.
*Productus biseriatus* Hall.
*Rhynchonella wortheni* Hall.
*Rhynchonella macra* Hall.
*Pugnax grosvenori* Hall.
*Dielasma formosa* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subaequalis* Hall.
*Spirifer subcardiformis* Hall.

*Spirferina spinosa* N. & P.
*Reticularia setigera* Hall.
*Eumetria marcyi* (Shum.)
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Nucula shumardana* Hall.
*Conocardium catastomum* Hall.
*Conocardium meekanum* Hall.
*Myalina* sp.
*Aviculopecten* sp.
*Goniophora plicata* Hall?
*Microdon subellipticus* Hall.
*Microdon oblongus* Hall.
*Microdon ellipticus* Whitf.?
*Cypricardinia indianensis* Hall.
*Dentalium* sp.
*Lepteopsis levettei* (White).
*Pleurotomaria humilis* Hall.
*Pleurotomaria piasaensis* Hall.
*Pleurotomaria meekana* Hall.
*Pleurotomaria subglobosa* Hall.
*Pleurotomaria* (several sp.)
*Bellerophon sublaevis* Hall.
*Straparollus spergenensis* (Hall).
*Murchisonia vermicula* (Hall).
*Cyclonema levenworthna* Hall.
*Naticopsis carleyana* Hall.
*Bulimorpha elongata* Hall.
*Holopea proutana* Hall.
*Platyceras acutirostris* Hall.
*Orthoceras* sp.
*Leperditia carbonaria* Hall.
*Phillipsia* sp.

W 44. Hull's Hollow, Madison County. (See p. 93.)

*Zaphrentis* sp.
*Platycrinus huntsvilliae* Troost.
*Fistulipora spergenensis* Rom.
*Fenestella serratula* Ulr.?
*Cystodictya lineata* Ulr.
*Worthenopora spatulata* (Prout.)
*Orthothetes minutus* Cum.
*Rhipidomella dubia* Hall.
*Productus altonensis* N. & P.
*Productus biseriatus* Hall.
*Camarophoria subcuneata* Hall.
*Pugnax grosvenori* Hall.
*Dielasma formosa* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subaequalis* Hall.
*Spirifer subcardiiformis* Hall.
*Reticularia setigera* Hall.
*Eumetria marcyi* (Shum.)
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Conocardium meekanum* Hall.
*Bellerophon sublaevis* Hall.
*Straparollus spergenensis* Hall.
*Holopea proutana* Hall.
*Platyceras circularis* Rowley.

W 45. Hull's Hollow, Madison County. (See p. 92.)

*Pentremites conoideus* Hall.
*Productus biseriatus* Hall.
*Reticularia pseudolineata* Hall.

W 42. Hopp Hollow, Madison County.. (See p. 93.)

*Monilopora beecheri* Grab.
*Fistulipora spergenensis* Rom.
*Anisotrypa fistulosa* Ulr.?
*Fenestella tenax* Ulr.
*Fenestella serratula* Ulr.
*Fenestella multispinosa* Ulr.
*Hemitrypa proutana* Ulr.
*Polypora simulatrix* Ulr.
*Polypora varsoviensis* Prout?
*Polypora internodata* Cum.
*Polypora spininodata* Ulr.
*Rhombopora bedfordensis* Cum.?.
*Cystodictya lineata* Ulr.
*Proutella discoidea* (Prout.)
*Worthenopora spatulata* (Prout.)
*Orthothetes minutus* Cum.
*Productus altonensis* N. & P.
*Productus biseriatus* Hall.
*Productus indianensis* Hall.
*Pugnax grosvenori* Hall.
*Dielasma formosa* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subaequalis* Hall.
*Spirifer subardiiformis* Hall.
*Spiriferina* sp.
*Reticularia pseudolineta* Hall.
*Eumetria marcyi* (Shum.)
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Straparollus spergenensis* Hall.
*Griffithides* sp.
*Phillipsia* sp.

U 48. NEAR COLUMBIA, MONROE COUNTY. (See p. 95.)

*Zaphrentis spinulosa* E. & H.
*Zaphrentis* sp.
*Amplexus* sp.
*Monilopora beecheri* Grab.
*Pentremites conoideus* Hall.
*Tricoelocrinus obliquatus* Roem.
*Metablastus bipyramidatis* Hall.
*Synbathocrinus swallovi* Hall?
*Batocrinus irregularis* Casseday.
*Dichocrinus oblongus* W. & W.
*Talarocrinus simplex* Shum.
*Archaeocidaris* sp.
*Stenopora* sp.
*Lioclema punctata* (Hall).
*Fenestella tenax* Ulr.
*Fenestella compressa* Ulr.
*Fenestella regalis* Ulr.?
*Polypora biseriata* Ulr.
*Fenestralia st. ludovici* Prout.
*Rhombopora bedfordensis* Cum.
*Cystodictya lineata* Ulr.
*Worthenopora spatulata* (Prout.)
*Worthenopora spinosa* Ulr.
*Orthothetes minutus* Cum.
*Rhipidomella dubia* Hall.
*Productus altonensis* N. & P.
*Productus biseriatus* Hall.
*Strophalosia?* sp.
*Pugnax grosvenori* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subaequalis* Hall.
*Spirifer subcardiiformis* Hall.
*Spiriferina spinosa* N. & P.
*Reticulari apseudolineata* Hall.
*Eumetria marcyi* (Shum.)
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Platyceras acutirostris* Hall.
*Phillipsia* sp.
Fish teeth.

U 56. 1½ MILES SOUTH OF COLUMBIA, MONROE COUNTY. (See p. 95.)

*Zaphrentis spergenensis* Worthen.
*Pentremites conideus* Hall.
*Talarocrinus simplex* Shum.
*Stenopora* sp.
*Fenestella tenax* Ulr.
*Hemitrypa proutana* Ulr.
*Rhombopora bedfordensis* Cum.
*Cystodictya lineata* Ulr.
*Cystodictya ocellata* Ulr.
*Worthenopora spatulata* (Prout.)
*Productus altonensis* N. & P.
*Productus biseriatus* Hall.
*Dielasma formosa* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subcardiiformis* Hall.
*Deltodus* sp.
*Cladodus* sp.

W 236. NEAR CHALFIN BRIDGE, MONROE COUNTY. (See p. 95.)

*Orthothetes minutus* Cum.
*Rhipidomella dubia* Hall.
*Productus altonensis* N. & P.
*Pugnax grosvenori* Hall.
*Spirifer bifurcatus* Hall.
*Reticularia pseudolineata* Hall.
*Eumetria marcyi* (Shum.).
*Seminula trinuclea* Hall.
*Allorisma* sp.
*Deltodus* sp.

W 235. NEAR BROWNSBURG, MONROE COUNTY.

*Orthothetes* sp.
*Rhipidomella dubia* Hall.
*Spirifer subcardiiformis* Hall.
*Seminula trinuclea* Hall.

W233. MISSISSIPPI RIVER BLUFF, OPPOSITE RENAULT STATION, MONROE CO.

*Zaphrentis cassedayi* E. & H.
*Fistulipora spergenensis* Rom.
*Fenestella* sp.
*Cystodictya* sp.
*Orthothetes minutus* Cum.
*Rhipidomella dubia* Hall.
*Productus altonensis* N. & P.
*Productus biseriatus* Hall.
*Pugnax grosvenori* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Spirifer subcardiiformis* Hall.
*Reticularia pseudolineata* Hall.
*Eumetria marcyi* (Shum.).
*Athris densa* H. & C.
*Seminula trinuclea* Hall.
*Macrodon* sp.
*Aviculopecten* sp.
*Bellerophon sublaevis* Hall.
*Platyceras acutirostris* Hall.
*Griffithides* sp.

W 263. ABANDONED QUARRIES, SWAN CREEK, EAST OF ANNA, UNION COUNTY.

*Endothyra baileyi* Hall.
*Zaphrentis spergenensis* Worthen?
*Zaphrentis* sp.
*Cystelasma rugosum* Ulr.?
*Syringopora* sp.
*Palaeacis cuneiformis* E. & H.
*Pentremites koninckana* Hall.
*Platycrinus huntsvillae* Troost.
*Melonites?* (plates).
*Rhipidomella dubia* Hall.
*Productus punctatus* Martin.
*Productus cora* D'Orb.
*Camarophoria wortheni* Hall.
*Dielasma formosa* Hall.
*Dielasma turgida* Hall.
*Reticularia pseudolineata* Hall.
*Eumetria marcyi* (Shum.)
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Nucula shumardana* Hall.
*Aviculopecten* sp.
*Goniophora? plicata* Hall.
*Dentalium* sp.
*Eotrochus concavus* (Hall.)
*Bellerophon* sp.
*Bucanopsis textiles* Hall.
*Straparollus spergenensis* Hall.
*Strophostylus carleyana* Hall.
*Bulimorpha bulimiformis* Hall.
*Orthoceras epigrus* Hall.
*Griffithides* sp.
*Psammodus* sp.
*Ctenacanthus* sp.

W. 264. OUTCROP BY ROADSIDE, SWAN CREEK, A LITTLE LESS THAN ½ MILE NORTH OF LAST LOCALITY, UNION COUNTY.

*Orthothetes* sp.
*Productus cora* D'Orb.
*Productus* sp.
*Dielasma formosa* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Eumetria marcyi* (Shum.).
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Aviculopecten* sp.
*Enchostoma* sp.

W. 265. OUTCROP BY ROADSIDE, SWAN CREEK, A LITTLE LESS THAN ¼ MILE NORTH OF LAST LOCALITY, UNION COUNTY.

*Pentremites konincki* Hall.
*Orthothetes* sp.
*Productus* sp.
*Dielasma formosa* Hall.
*Dielasma turgida* Hall.
*Spirifer bifurcatus* Hall.
*Eumetria marcyi* (Shum.)
*Seminula trinuclea* Hall.
*Cliothyris hirsuta* Hall.
*Nucula shumardana* Hall.
*Nucula* sp.
*Goniophora? plicata* Hall.
*Lepetopsis* sp.
*Bembexia elegantula* (Hall)?
*Porcellia* sp.
*Strophostylus carleyana* Hall.
*Griffithides* sp.

# LOWER PALEOZOIC STRATIGRAPHY OF SOUTH-WESTERN ILLINOIS.*

(BY T. E. SAVAGE.)

## Contents.



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## INTRODUCTION.

The following paper is a preliminary statement concerning the pre-Mississippian formations that occur in the southwest portion of Illinois. A detailed report on the stratigraphy and paleontology of these terranes in the above mentioned area is in preparation by the writer. The field work on which the report is based was done during the summer of 1907, under the auspices of the Illinois Geological Survey; while the paleontological study was made at the Peabody Museum, Yale University, under the direction of Professor Charles Schuchert. To the latter the writer wishes to acknowledge his indebtedness for valuable assistance in the study and interpretation of the faunas and the data that were collected.

The pre-Mississippian beds in this portion of the State underlie the surficial materials over an area 150 miles in extent. They appear in the southwest corner of Jackson county in the Back Bone and Bake Oven ridge, at the south end of Walker ridge, and at Bald Rock and southward on the east side of Big Muddy river. In Union and Alexander counties they extend from the flood-plain of the Mississippi eastward to a general line passing within about one mile west of the towns of Alto Pass, Mountain Glen, Jonesboro and Mill Creek, to a point nearly two and one-half miles southeast of Elco, whence the line separating the Devonian from the younger formations trends toward the southwest past the Diswood postoffice, to near the middle of section 28, T. 15 S., R. 2 W. Eastward they are bordered by Mississippian beds, while along the southern edge sands and clays of Tertiary age lie upon the flanks of these older formations. Occasional patches of Tertiary gravels occur within the region under discussion.

This small area is exceedingly interesting geologically because of the fact that some of the formations here represented do not appear further north anywhere in the Mississippi valley. The successive beds were deposited in a basin of the Interior or Mississippian sea which, during a great part of the time, was more or less separated from that in which the older strata in other portions of the State were laid down. Owing to its proximity to Ozarkia this basin was subjected to vertical movements and therefore to variable conditions of sedimentation, very different from those that prevailed during the same time over the more northern areas.

## EARLIER GEOLOGICAL WORK.

In volume III of the Geological Survey of Illinois, Professor Worthen published reports on the geology of Jackson, Union and Alexander counties in which he describes, in a general way, the stratigraphy of the region under discussion. In 1897 Dr. Weller* published a list of fossils collected at the Bake Oven, in Jackson county, with a discussion of the relations of these to the Middle Devonian faunas of other localities.

* Weller: Jour. Geol., vol. 5, pp. 625-635. 1897.

No careful detailed study of the lower Paleozoic beds of this region as a whole has ever been attempted previous to the present work. This neglect was doubtless due, in part, to the small size of the area; to the absence of the more important economic deposits; and to the fact that the deformations and unconformities occuring in this region have made the geological relations of the beds obscure; and that many of the formations present here cannot be correlated with those in other portions of the State.

## COMPOSITE SECTION OF THE PRE-MISSISSIPPIAN STRATA OCCURRING IN SOUTHWESTERN ILLINOIS.

The general relations of the Lower Paleozoic formations in southwestern Illinois may be represented in a generalized section as follows:

| System. | | Correlations. | Location of sections. | Descriptions of horizons. |
|---|---|---|---|---|
| DEVONIAN. | Upper Devonian. | New Albany Black Shale, Chattanooga Black Shale, Ohio Blk. Shale—86 ft. | Union county, N. E. 1/4 sec. 34, T. 11 S., R. 2 W. Union county, S. E. 1/4 sec. 1, T. 13 S., R. 2 W. | 10c. Greenish-blue shale, fossils almost none—29 ft.<br>10b. Black shale with few fossils, but carrying numerous very small balls of iron pyrite from 1/8 to 1/2 inch in diameter—21 ft.<br>10a Brown to black, siliceous shale or shaly limestone with *Leiorhynchus globuliformis* and *Reticularia laevis*—36 1/2 ft. |
| | Middle Devonian. | Hamilton—70 ft. | Union county, N. E. 1/4 sec. 34, T. 11 S., R. 2 W. Jackson county, section at Back Bone, near Grand Tower. | 9c. Light gray siliceous limestone, in part oolitic, characterized by *Chonetes coronatus, Cranaena romingeri, Spirifer pennatus, S. audaculus, Tropidoleptus carinatus* and *Vitulina pustulosa*—7 ft.<br>9b. Yellowish-brown siliceous or shaly limestone with few fossils—25 ft.<br>9a. In the north are dark colored, fine grained limestones with *Microcyclus discus, Chonetes yandellanus, Eunella attenuata, Parazyga hirsuta, Spirifer fornacula* and *S. pennatus*. In the south are gray or leached limestones with *Athyris spiriferoides. Delthyris sculptilis, Spirifer granulosus, Rhipidomella penelope*—38 ft. |
| | | Marcellus—28 ft. | N. 1/2 sec. 34, T. 13 S., R. 2 W., Union county. | 8a. Rather soft shale weathering to a yellowish-brown color, with *Leiorhynchus limitare*—28 ft.<br>This horizon is not present at the north in Jackson county. |
| | | | | The Onondaga is well developed in Jackson county where it passes without a break into the Hamilton. In the southern part of Union county there is a break, and the Onondoga is represented only by the basal sandstone, 7a of section. |

*Composite Section of the Pre-Mississippian Strata*—Continued.

| System. | | Correlations. | Location of sections. | Descriptions of horizons. |
|---|---|---|---|---|
| DEVONIAN. | Middle Devonian. | Onondago—$156\frac{2}{3}$ feet. | Back Bone, Jackson county. | 7i. Heavy layers of very hard, gray, coarsely crystaline limestone; containing corals, *Chonetes konickianus, Pholidostrophia iowensis, Productella spinulicosta* and *Stropheodonta concava. Strophalosia truncata* is abundont in the lower half, while *Productella spinulicosta* is common in the upper part—26ft. |
| | | | | 7h. Layer of dark colored limestone largely composed of shells of *Chonetes konickianus* var.—3 5-6 ft. |
| | | | | 7g. Thin bedded, hard, gray limestone, layers 2-10 inches thick. Fossils rare, *Chonetes konickianus* var. common in the upper part and *C. pusillus* with *Stopheodonta concava* in the lower—15 ft. |
| | | | | 7f. Hard, gray, impure limestone with few fossils—21 ft. |
| | | | Bake Oven, Jackson county. | 7e. Dark gray, impure limestone with thin chert bands near the top. Fossils numerous, *Nucleocrinus verneuili, Rhynchonella gainesi, Meristella barrisi, Spirifer acuminatus, Stropheodonta patersoni,* etc.—$8\frac{1}{3}$ ft. |
| | | | | 7d. Dark gray, impure, fine-grained limestone. *Chonetes mucronatus* abundant in a zone near the middle. Other fossils are *Rhipidomella vanuxem, Spirifer grieri, Stropheodonta patersoni, S. perplana,* and *Phacops cristata*—11 ft. |
| | | | | 7c. Heavy layers of light gray, subcrystalline limestone. Fossils abundant. *Coscinium cribriformis, Centronella glansfagea, Spirifer duodenarius, S. macrothyris* and *Odontocephalus aegeria* present throughout—38 ft. |
| | | | | 7b. Alternating layers of light gray, arenaceous, subcrystalline limestone and coarse-grained sandstone, containing *Centronella glansfagea, Meristella near lentiformis, Rhipidomella cf. musculosa, Spirifer duodenarius* and *S. macrothyris*—$15\frac{1}{2}$ ft. |
| | | | N.W. ¼ sec. 26, T. 12 S., R. 2 W.; also S. W. ¼ sec. 26, T. 13 S., R. 2 W., Union county. | 7a. Bed of more or less iron-stained sandstone, in places soft and friable, at other points cemented by a deposit of iron or silica, containing *Michelinia stylopora, Aulacophyllum* sp., *Centronella glansfagea, Spirifer duodenarius, S. macrothyris* and *Odontocephalus arenarius*—18 ft. |

*Composite Section of the Pre-Mississipian Strata*—Continued.

| System. | | Correlations. | Location of sections. | Descriptions of horizons. |
|---|---|---|---|---|
| DEVONIAN. | Oriskanian. | Upper Oriskany—Clear Creek chert, Camden chert, 237 feet. | Schaffer's branch, 2 miles west of Jonesboro, N. W. 1/4 sec. 26, T. 12 S., R. 2 W. Union county. | 6e. Bed of light gray chert in layers 3-9 inches thick, *Amphigenia curta, Chonostrophia reversa, Eodevonaria melonica, Schuchertella pandora* and *Spirifer worthenanus* abundant—5½ ft.<br>6d. Reddish-brown, friable sandstone with *Michelinia stylopora, zaphrentis* sp., *Amphigenia curta* and *Spirifer duodenarius*—2 5-6 ft.<br>6c. Layers of light gray chert, 4-8 inches thick. *Anoplia nucleata, Chonostrophia reversa, Eodevonaria melonica, Schuchertella pandora* and *Spirifer worthenanus* —1½ ft. |
| | | | N. W. 1/4 sec. 10, T. 12 S., R. 2 W., Union county.<br>N. E. 1/4 sec. 12, T. 12 S., R. 3 W., Union county.<br>N. E. 1/4 sec. 36, T. 14 S., R. 2 W., Union county. | 6b. Reddish-brown, friable sandstone—2 ft.<br>6a. Bed of light colored chert layers, in qlaces alternating with impure siliceous limestone, and at other points composed wholly of chert bands. Fossils most abundant in the upper part. *Amphigenia curta, Anoplotheca flabellites, Eatonia peculiaris, Eodevonaria melonica, Chonostrophia reversa, Schuchertella pandora, Spirifer worthenanus,* and *S. hemicyclus* common in the upper part —225 ft.<br>(In the southern part of Union county the lower chert layers are massive and contain but few fossils. In the pit worked by the M. & O. railroad, 1½ miles north of Tamms, in Alexander county, may be seen an exposure of more that 100 feet in which few fossils were found.) |
| | | | | A break in sedimentation. |
| | Helderbergian. | New Scotland, about 158 feet. | South end of Back Bone, Gra'd Tow'r and Bald Rock, Jackson county. | 5b. Heavy bedded, light colored, coarsely crystalline limestone, with *Eatonia singularis, Spirifer macropleura, S. perlamellosus, Stropheodonta beckii,* and *Strophonella punctulifera*—about 58 ft. |
| | | | Grand Tower rock, and Frisco railro'd cut a few rods further west, in Missouri. | 5a. Layers of impre, shaly limestone alternating with bands and nodules of chert; in the upper portion occur *Dalmanella subcarinata, Meristella laevis, Spirifer cyclopterus, S. perlamellosus* and *Strophonella punctulifera*—100 ft.<br>(The horizon of 5a appears to belong immediately below 5b. It is present at Bald Rock, and in the river bluffs further south, but the fossils were not so abundant at the later points.) |

*Composite Section of the Pre-Mississippian Strata*—Continued.

| System. | | Correlations. | Location of sections. | Descriptions of horizons. |
|---|---|---|---|---|
| | | | | A long break in sedimentation. |
| UPPER SILURIAN OR SILURIAN. | Niagaran. | Clinton—Dayton, Ohio—Clinton<br>Interior or Western Clinton, 75 feet. | 2 miles N. E. of Gale, N. W. ¼ sec. 27, T. 14 S., R. 3 W., also ¼ mile S. and S. E. of Gale, Alexander county. | 4c. Pink, mottled limestone, in layers 10-4 inches thick, containing many small im mature brachiopods, with which occu *Plectambonites transversalis*, *Rafine quina mesacosta* and *Spirifer* near *su cata*—23 ft.<br>4b. Layers of gray to drab colored limestone 2-6 inches thick, alternating with thi bands of chert and characterized by suc typical Clinton fossils as *Stricklandini triplesiana* and *Triplecia ortoni*—6 ft.<br>4a. Bed of tough, gray limestone in layers 3- inches thick which are imperfectly sep arated by 2 to 4-inch partings of cher Fossils rare—0-46 ft.<br>(4a is wanting at some points in thi area.) |
| | | | | A break in deposition. |
| MIDDLE SILURIAN. | Alexandrian. | Cape Girardeau Limestone, about 44 feet. | Along the river 1½ miles north of Thebes, and also 1 mile south of Thebes, in Alexander county. | 3c. Coarse-grained, somewhat oolitic limestone in layers 12-18 inches thick; *Atryp rugosa*, *Rhynchotreta* sp., *Schuchertell subplanus*, *Whitfieldella billingsana* an *Lichas breviceps clintonensis* common—3½ ft.<br>3b. Fine-grained, dark colored, shaly limeston in layers 4-10 inches thick, characte ized by *Rafinesquina mesacosta*, *Sch chertella subplanus* and *Dalmanit danae*—2½ ft.<br>3a. *Cape Girardeau limestone:* Fine-graine black, brittle limestone, layers 1-4 inche thick, separated from each other b thin lenses or partings of calcareous sha on the surface of which are expose crinoids, *Rafinesquina mesacosta*, *Rhyn chotrema* sp., *Schuchertella missour ensis* and *Cornulites tenuistriata*—33-3 feet. |
| | | | | A probable short break in sedimentation. |
| LOWER SILURIAN OR ORDOVICIAN. | Cincinnatian. | Richmond — Maquoketa, 91 feet. | East bank of Mississippi river ½ mile south of Gale, Alexander county. (9b in the south part of Thebes.) | 2b. Bed of grayish-blue shale in which 1-inc bands of more resistant calcareous sha occur 4-6 inches apart, bearing *Rhy chotrema inaequivalve?*, *Strophomen sulcata?* *Zygospira recurvirostra*, *Conr della* sp. and *Isotelus* sp. not rare—18 f<br>2a. *Thebes sandstone and shale:* Bluish t brown, shaly sandstone in layers ½ t 2½ feet thick; the upper prtion thi ner bedded with a larger admixture c shale. *Lingula* cf. *covingtonensis* th only fossil found in the upper par while *Isotelus* sp., occurs near the base—73 ft. |

*Composite Section of the Pre-Mississippian Strata*—Concluded.

| System. | | Correlations. | Location of sections. | Descriptions of horizons. |
| --- | --- | --- | --- | --- |
| | | | | A break in Deposition. |
| LOWER SILURIAN OR ORDOVICIAN. | Mohawkian. | Galena-Trenton, 68-80 feet. | East bank of Mississippi river, 3/8 mile S. of Thebes, S. E. 1/4 sec. 17, T. 15 S., R. 2 W. | 1a. Light gray, coarsely crystalline limestone, in regular layers 3-48 inches thick; the upper part characterized by the fossils *Receptaculites oweni, Hebertella* near *occidentalis, Platystrophia biforata, Plectorthis plicatella, Cytolites ornatus* and *Platymetoous cucullus;* while the lower portion is marked by *Receptaculites oweni, Rhynchotrema inaequivalve, Parastrophia hemiplicaa* and *Triplecia* sp.—68-80 ft. |

## ORDOVICIAN.

*Galena-Trenton*—A thickness of 68 to 80 feet of this formation is exposed in Alexander county. It appears at two points adjacent to the Mississippi river where the waters of that stream have cut across low arches which bring the Galena limestone above the level of the water. One of these exposures is a short distance below Thebes, where a thickness of about 68 feet of the limestone may be studied. The second fold crosses the river about two miles north of Thebes, a short distance west of the village of Gale, where the limestones may again be seen on Little Rock Island.

The Galena formation is here a light colored, crystalline, non-magnesian limestone, in layers from a few inches to four feet in thickness, which is imperfectly exposed in the upper part. The lowest layers contain in abundance, *Receptaculites oweni, Hebertella* near *occidentalis, Parastrophia hemiplicata, Platystrophia biforata, Rafinesquina alternata, Rhynchotrema inaequivalve, Strophomena emaciata, Triplecia* n. sp., and the trilobites *Bronteus lunatus, Bumastus trentonensis, Illaenus americanus, Isotelus maximus,* and *Platymetopus cucullus.* Eighteen feet above low water *Crania trentonensis, Cyrtolites ornatus, Plectorthis plicatella* and *Remopleurites striatulus* are assosiated with most of the above mentioned forms. In the middle and upper parts the white color is in places mottled with pink, and the fossils become much less abundant. *Receptaculites oweni* is still common while *Crania trentonensis, Hebertella* near *occidentalis, Platystrophia biforata, Rafinesquina alternata, Rhynchotrema inaequivalve* and *Triplecia* n. sp. persist in diminished numbers.

This facies of the Galena resembles, in its fossils and lithology, the Kimmswick limestone of Ulrich, also described by Weller from Jersey and Calhoun counties.* The basin in which it was deposited was probably somewhat separated from that which received the sediments of the more northern dolomite phase of the Galena.

*Weller: Illinois State Geol. Surv., Bull. No. 4, p. 222.

*Richmond-Maquoketa*—The beds that belong to the Richmond formation have an aggregate thickness of 91 feet. This formation succeeded that of the Galena after a long land interval. All of the Utica and Lorraine deposits are wanting, and seemingly much of the Richmond is also absent. The formation in southwest Illinois consists of two members, 2a and 2b of the general section. The lower one (2a) is a sandstone or sandy shale—"Thebes sandstone and shale"—which is exposed along the flanks of the Thebes and Gale anticlines, and in the intervening trough. The materials are reddish brown where weathered, and blue where not changed by the atmosphere. The lower part is a sandstone, thick bedded and in regular layers, which is well exposed at the east end of the railroad bridge at Thebes. In the upper half the layers are thinner and, where much weathered, appear decidedly argillaceous. This more shaly horizon is well exposed in the river bank three-fourths of a mile south of Gale. *Lingula* cf. *covingtonensis* occurs sparingly throughout the sandy shale of this member.

The upper member is a bed of fossiliferous, bluish shale (2b of the section.) It is exposed in the bank of the river and in a cut along the Illinois Central railway about three-fourths of a mile south of Gale, where it overlies the "Thebes sandstone and shale" member. The bed has a thickness of 18 ft., and contains *Cyclocystoides* n. sp., *Phylloporina* near *granistriata, Dalmanella testudinaria, Plectambonites sericea, Rhynchotrema inaequivalve?, Strophomena sulcata?, zygospira recurvirostra, Conradella* near *fimbriata,* and species of *Isotelus* resembling *I. susae* and *I. platycephalus.* The lithologic and faunal change from the Thebes sandstone member to this blue shale is abrupt, which may indicate a break between the two beds. The fauna reminds one much of the Black river formation, but as it occurs above the *Rhynchotrema capax* zones in Missouri, and its life assemblage is not at all that of the overlying Cape Girardeau limestone, it must belong in the Richmond with the Thebes sandstone.

Neither of these members contain *Rhynchotrema capax,* the widely distributed guide fossil to the Richmond. However, across the river, in the vicinity of Cape Girardeau, Mo., were found thin layers of gray, sub-crystalline limestone, 5-7 feet thick, which contain *Rhynchotrema capax* and other Richmond fossils in abundance. This zone occurrs just above the white, heavy-bedded Galena limestone, and immediately below the Thebes sandstone. The same limestone horizon, bearing *R. capax,* is doubtless present in Ilinois, but the contact between the Galena and the Richmond formations was nowhere found exposed.

The above shales and sandstone do not extend so far north as does the underlaying limestone. The sea in which they were deposited probably washed the shores of the Ozarkian land area a few miles to the west which, during late Richmond time, was the source of the sediments that make up these terrigenous beds.

## MIDDLE SILURIAN.

*Alexandrian*—The beds referred to this formation are exposed in Alexander county to a thickness of 44 feet. They include the Cape Girardeau limestone and the overlying beds containing *Dalmanites danae* and *Whitfieldella billingsana.* The Cape Girardeau limestone is well

exposed about two miles south of Thebes, in the bank of the river and along the streams in that immediate vicinity. It is also seen in a cut along the Illinois Central railroad and in the river's bank one and one-half miles north of Thebes. In the former locality this member is nearly 40 feet thick, and consists of black, fine grained, brittle limestone, in thin layers which are often separated by narrow partings of dark, calcareous shale. This zone has a rich fauna that appears abruptly at this horizon. Among the forms are several species of crinoids, *Dalmanella* near *elegantula, Homoeospira* n. sp., *Leptaena rhomboidalis, Rafinesquina mesacosta, Rhynchotreta* n. sp., *Schuchertella missouriensis, Zygospira* n. sp., *Cornulites tenuistriata, C. incurvus, Platyostoma* near *niagarensis, Strophostylus* sp., *Acidaspis halli, Calymene* sp., *Cyphaspis girardeauensis* and *Encrinurus* sp.

At the exposure north of Thebes the Cape Girardeau limestone rests directly upon the fossiliferous blue shale (2b of section). This member is succeeded by a bed of dark gray limestone, oolitic in the upper part, which contains *Favosites* sp., *Stromatopora* sp., *Atrypa rugosa, Clorinda* n. sp., *Homoeospira* n. sp., cf *Hindella umbonata, Leptaena rhomboidalis, Platystrophia biforata, Rafinesquina mesacosta, Rhynchotreta* n. sp., *Schuchertella subplanus,* (probably a coarse form of *S. missouriensis*) *Strophomena* sp., *Whitfieldella billingsana, Dalmanites danae, Dalmanites* sp., and *Lichas breviceps clintonensis.*

There are here no diagnostic fossils of the Richmond. The genera *Favosites, Stromatopora, Atrypa, Whitfieldella, Homoeospira, Schuchertella* and *Clorinda* do not occur in American Ordovician strata, while *Atrypa rugosa* and *Lichas breviceps clintonensis* are found in the Silurian. On the other hand the fauna is not directly related to that of the Clinton, from which formation it is separated by a marked erosional unconformity. Schuchert cites* a fauna from Edgewood in eastern Missouri, collected by Ulrich, which corresponds closely with the above. Since there seems to be no direct time equivalent of these beds in the Ordovician or in the Silurian, as generally defined, the horizons 3a to 3c are classed as Middle Silurian strata that more or less completely bridge the lost interval between the Cincinnation and the Clinton. For these beds the time term Alexandrian is proposed, from Alexander county, Illinois, where they are well exposed; the term to have the same rank as Cincinnatian, which it immediately follows.

## SILURIAN.

*Clinton*—The limestone of this formation has here a maximum thickness of 75 feet. One-half mile southeast of Gale it immediately overlies the shale member (2d of section) above the Thebes sandstone, all of the Alexandrian beds having been cut out by erosion prior to the deposition of the Clinton. One and one-half miles north of Thebes the Clinton limestone rests on the *Whitfieldella billingsana* zone (3c of section), while two miles south of Thebes it immediately overlies the Cape Girardeau limestone (3a of section). The upper part of the Clinton (4c of section) consists of heavy bedded, pink or mottled

*Journal of Geology, Vol. XIV, pp. 728-729, 1906.

limestone, 23 feet thick, which contains many small, immature brachiopods besides *Plectambonites transversalis, Rafinesquina mesacosta, Spirifer* near *sulcata, Illaenus* sp., and a few new species of Orthoceras. Below this pink limestone lie 6 feet of thin bedded, dark gray limestone with narrow bands of chert (4b of the section). The limestone layers contain *Favosites favosus, Halysites catenulatus, Stromatopora* sp., *Atrypa rugosa, Orthis* cf *davidsoni, Orthis flabellites, Plectambonites transversalis,* and var. *elegantula, Stricklandinia triplesiana* and *Triplecia ortoni.*. The above fauna corresponds with that of the Interior or Western Clinton, as described by Foerste from the region of Dayton, Ohio.

The lower portion of this formation (4a) is well exposed in the vicinity of Gale and two miles further north along Sexton creek, in the N. W. ¼ of sect. 27, T. 14 S., R. 3 West., where it consists of 46 feet of thin bedded, gray limestone, the layers of which are separated by narrow chert bands.

The thickness of the Clinton is variable. It does not exceed 29 feet in the exposure south of Thebes, while near Gale, and along Sexton creek and in the river bluff two miles east of McClure, the aggregate thickness is 75 feet. Where the formation is thinnest it is the lower and not the upper layers that are absent.

## DEVONIAN.

*Helderbergian*—The rocks of Helderbergian age in Illinois correspond with the New Scotland formation of New York. They succeed the Clinton after an exceedingly long land interval represented by all of the Silurian after the Clinton, and the Coeymans of the Lower Devonian. In New Scotland time the Interior or Mississippian sea was much more restricted than during the Clinton. It extended as an embayment from the gulf region as far north as Jackson county, Illinois. It spread west to Oklahoma and east as far as southeast Tennessee. It was separated by a land barrier from the Atlantic embayment( Cumberland basin) which occupied parts of New York, Maryland and northeastern Tennessee; and it is probable that the Kankakee barrier, as defined by Schuchert, prevented its spreading far to the north and northwest.

The New Scotland formation in Union and Jackson counties has an aggregate thickness of more than 160 feet. The lower portion, for a thickness of 100 feet, consists of shaly limestone with interbedded bands of chert. This phase is exposed in the lower part of Bald Rock, four miles southeast of Grand Tower on the Big Muddy river. It appears in the east bluff of the Mississippi river for some distance south from this point. It makes up Tower Rock, in the Mississippi river channel, west of Grand Tower, and it is exposed on the Missouri side of the river, in the quarry and in the cut made by the Frisco railroad company, a short distance south and west of this rock. At the latter point were collected *Streptelasma recta, Dalmanella subcarinata, Leptaena rhomboidalis, Leptaenisca adnascens, Meristella laevis, Spirifer cyclopterus, S. peramellosus, Stropheodonta punctulifera, Hausmannia* sp. and *Phacops logani* var.

The upper 58 feet of the New Scotland formation consists of light gray, heavy bedded, coarsely crystalline limestone. This facies is exposed in the south end of the Back Bone ridge where a fault brings it above the level of the flood plain. It forms the upper part of Bald Rock where another fault has raised it to the level of the adjacent Chester limestone, of Mississippian age. It occurs in the east bank of Clear creek in sections 23 and 24, T. 11 S., R. 3 West. The beds furnished *Aspidocrinus scutellaeformis, Anoplotheca concava, Eatonia singularis, Leptaenisca concava, Megalanteris condoni, Meristella arcuata?, Oriskania sinuata* n. var., *Spirifer concinnus, S. cyclopterus, S. macropleura, S. perlamellosus, Stropheodonta beckii, S. varistriata,* and var. *arata, Strophoella punctulifera, Uncinulus nobilis?* and *U. nucleolata.*

*Oriskanian* (Clear Creek cherts, Camden cherts)—The Clear Creek formation consists of light gray to yellowish colored cherts that are usually in thin layers but which in the lower part are sometimes three to five feet in thickness. At some points the cherts are thoroughly leached and decomposed, and occur as a fine white powder that can be dug with a shovel, and is utilized for commercial purposes. This formation rests with erosional unconformity upon the New Scotland beds at the south end of the Back Bone ridge. Its fauna corresponds with that of the Camden cherts in western Tennessee. The beds represent deposits of the Upper Oriskany time, as is indicated by the interwedging of the upper chert layers with those of the basal portion of the succeeding Onondaga (see 6a to 6e of section). The chert formation has a thickness in Illinois of about 237 feet. Fossils are somewhat rare in the lower portion but in the middle, and especially in the upper, part there is a rich fauna, including *Michelinia* n. sp., *Ambocoelia* cf. *umbonata, Amphigenia curta, Anoplia nucleata, Anoplotheca flabellites, A. fimbriata, Centronella glansfagea, Chonostrophia reversa, Cyrtina hamiltonensis, Eatonia peculiaris, E.* cf. *whitfieldi, Eodevonaria melonica, Stropheodonta perplana, Megalanteris condoni, Oriskania sinuata,* n. var., *Pholidops terminalis, Rhipidomella musculosa, Spirifer worthenanus, S. duodenarius, S. macrothyris, S. hemicyclus, S. tribulis, S.* cf. *murchisoni, Schuchertella pandora, Acidaspis tuberculata, Odontocephalus arenarius* and *Phacops cristata.*

These upper Oriskany beds were deposited near the north end of the Mississippian embayment which at this time was even more contracted than during the Helderbergian. The basin was remote from, and not connected with, the NewYork-Maryland province (Cumberland basin). It covered western Kentucky and Tennessee, and lapped over the southeast corner of Missouri and the east side of Arkansas, spreading an arm across northern Alabama.

*Onondaga*—The sedimentation of the Upper Oriskany time continued without a break into the Onondaga or Corniferous. The latter period was initiated by disturbances to the westward, in Ozarkia, which increased mechanical sedimentation in the Illinois area. These resulted for a time in the deposition, along the eastern shore of Ozarkia, of layers of sand containing Onondaga fossils alternating

with the return of the Oriskanian limestone conditions. Eventually sand deposition prevailed and there was spread over the region the basal sandstone of the Onondaga formation (7a of section), containing *Michelinia stylopora, Aulacophyllum* sp., *Amphigenia curta, Centronella glansfagea, Meristella* near *lentiformis, Rhipidomella musculosa, Spirifer duodenarius, S. macrothyris, Conocardium cuneus* and *Odontocephalus arenarius.*

Early in Onondaga time an elevation in the southern portion of Union and in Alexander county put a stop to further deposition in that locality, while farther north, in Jackson county, sedimentation was uninterrupted.

At the cut through the Back Bone and at the Bake Oven, a short distance north of Grand Tower, there is exposed a continuous section of the Onondaga formation showing a thickness of 115 feet. The beds consist largely of light colored, regularly bedded, more or less crystalline limestone which becomes arenaceous in the lower part. Fossils are abundant throughout the section.

The upper layers are marked by *Chonetes konickanus, Leptaena rhomboidalis, Pentamerella arata, P. papilionensis, Meristella rostrata, Rhynchonella gainesi, Spirifer acuminatus, S. grieri, S. macra, Stropheodonta patersoni, Conocardium trigonale* and *Onychodus sigmoides.* In the lower part *Nucleocrinus verneuili, Coscinium cribriformis, Centronella glansfagea, Leptaena rhomboidalis, Meristella barrisi, Pentamerella arata, Spirifer acuminatus, S. duodenarius, S. macrothyris, Stropheodonta patersoni, Dalmanites calypso, Odontocephalus aegeria* and *Onychodus sigmoides* are common.

During the Onondaga and the succeeding Hamilton time the warm waters from the gulf region, with their successive faunas, spread towards the northeast across Illinois and Indiana, passing around the north end of the Cincinnati axis, and mingled with those of the eastern embayment in western New York. Such water connections permitted free migrations within this sea, and explains the close correspondence between the various Middle Devonian faunas of southwestern Illinois and those of western Ontario and New York.

*Hamilton*—Throughout Hamilton time the Kankakee barrier or peninsula, extending from Ozarkia towards the northeast across Illinois, was largely effective in preventing the waters of the Interior or Mississippian sea from uniting with those of the Northwestern or Dakotan basin towards the northwest. As a result of this separation the deposits and the faunas of Hamilton time, in Illinois, belong to two distinct provinces. The phase of the Hamilton in the vicinity of Rock Island, and in Jersey and Calhoun counties, belongs to the Northwestern or Dakotan province; while that of the southwest Illinois belongs to the New York province.

The New York faunal phase of the Hamilton is well developed in the south part of Union county, in the north half of sect. 34, T. 13 S., R. 2 West, and further north in the N. E. ¼ of sect. 34, T. 11 S., R. 2 West. The formation is also represented by the upper beds near the north end of Back Bone ridge, in Jackson county.

At the first mentioned exposure there is at the base of the Hamilton 28 feet of yellowish-blue shale which contains *Leiorhynchus limitare*, both the character of the sediment and the fossils reminding decidedly of the Marcellus shale of New York. This shale rests unconformably (erosional) upon the basal sandstone member (7a) of the Onondaga. It is succeeded by a few feet of limestone which, in places, is much leached and very fossiliferous. *Athyris spiriferoides, Delthyris sculptilis, Rhipidomella penelope, Spirifer granulosus* and *Stropheodonta concava* being very common. At points further north the lower beds of the Hamilton consist of dark colored, impure limestone which succeeds the Onondaga without any apparent break. The characteristic fossils of these layers are *Microcyclus discus, Athyris vittata, Eunella attenuata, Spirifer fornacula, Conocardium cuneus* and *Onychodus sigmoides.*

The middle portion of the Hamilton limestone is dark colored and evenly bedded, and contains *Ambocoelia umbonata, Chonetes yandellanus, C. pusillus, Cranaena romingeri, Parazyga hirsuta, Pholidops oblata* and *Spirefer pennatus.* Above this horizon occurs about 25 feet of yellowish-brown, impure siliceous limestone with few fossils. Near the top of the formation occurs a few feet of hard, gray limestone containing *Chonetes coronatus, Rhipidomella vanuxemi, Spirifer audaculus, S. pennatus, Tropidoleptus carinatus* and *Vitulina pustulosa.*

*Upper Devonian*—During Upper Devonian time the Mississippian sea continued to expand, spreading the materials of this formation more widely than those of the preceding. In the N. E. ¼ of section 34, T. 11 S., R. 2 West, the lower deposits of the Upper Devonian are comfortable upon the Hamilton. There is here exposed a thickness of 33 feet of yellowish-brown (black where unweathered), siliceous, shaly limestone, cherty near the top, and marked by *Leiorhynchus globuliformis, L. mesacostalis, Reticularia laevis* and *Spirifer pennatus.* At other points this cherty phase is succeeded by 50 or more feet of greenish to black, almost barren shales. These siliceous and dark colored shales are probably the equivalent of the calico rock, a mottled and leached, siliceous shale, present further south in Union and Alexander counties. They doubtless correspond with the Chattanooga black shale, Ohio black shale, New Albany black shale, and the Lower Portage beds of other states.

## CONCLUSION.

The present studies have shown that the pre-Mississippian beds have a much wider distribution in southwestern Illinois than was formerly supposed. They have distinguished the presence of a bed of blue, fossiliferous shale (2b of section) containing the *Cyclocystoides* and *Phylloporina* fauna, immediately overlying the Thebes sandstone and shale horizon. They have demonstrated the presence, in this region, of Silurian beds corresponding with the Clinton formation in Ohio. They have shown that the massive, crystalline limestone underlying the Clear Creek cherts in Jackson and Union counties, belongs to the New Scotland formation of the Helderbergian. They have demonstrated the Upper Oriskany age of the Clear Creek

cherts. They have disclosed the absence of the greater portion of the Onondaga formation in Alxander county and in the southern portion of Union; and they have shown that the Hamilton formation, in Union county, continues upward without a break into the Lower Portage beds of the Upper Devonian.

# NOTES ON THE SHOAL CREEK LIMESTONE.

(By Jon A. Udden.)

## Contents

## INTRODUCTION.

A fundamental problem in the investigation of the coal fields of Illinois is the correct correlation of the productive veins. Sixteen different coal seams were recognized by the old geological survey, and were grouped in two divisions, the "Upper" coal measures, including the thin and unproductive coals, and the "Lower" coal measures, containing the thick and productive seams. A limestone formation supposed to be more or less continuous throughout the coal measure area of the State, and commonly called Carlinville or Shoal Creek limestone, was believed to mark the plane separating these two divisions. During the past season, several weeks were devoted by the writer to an attempt to trace the outcrops of this limestone in the southwest part of the State.

## EARLIER INVESTIGATIONS.

This limestone formation has been known under various names. In Illinois, Indiana and Kentucky, no less than six different local names have been applied to limestones, all of which are probably to be referred to this one horizon. The names Curlew, Shoal Creek, Carthage (?), Carlinville, New Haven and Somerville limestones are all believed to be synonomous for localities described in this State. Observations have not yet been carried far enough to make this quite certain.

The earliest observations on the limestone under consideration were made by Owen, in Kentucky. The Carthage limestone was noted in Union county, Kentucky, "one mile below Uniontown."* Its stratigraphic position in the Kentucky section† is between the Kentucky coals numbers 17 and 18. It is described as having a thickness of seven feet.

The Kentucky and Indiana coal fields were studied earlier than the Illinois field, and attempts were made in these early reports to correlate all of the coal horizons with those of the Pennsylvania fields, whose sections were better known. The first attempt at correlation of this kind was made by Owen in his report on the Kentucky coal measures,‡ where the relation of the Curlew sandstone and limestone

*Kentucky Geol. Surv., vol. 1, p. 60, 1856.
†Kentucky Geol. Surv., vol. 3, p. 18, 1857.
‡Kentucky Geol. Surv., vol. 3, pp. 13-23, 1857; vol. 4, p. 387, 1867.

was shown graphically, the limestone occurring beneath a heavy ledge of sandstone and above a thick conglomerate, the Curlew sandstone being considered the equivalent of the Mahoning sandstone of Pennsylvania.

Lesquereux in his Report on the Distribution of Geological Strata in the Coal Measures of Indiana* discusses the possible occurrence of the Curlew limestone in a section at Rockport, Spencer county, Indiana. It is doubtful, however, if the limestone in this section is the equivalent of the Curlew limestone of Kentucky, since no thickness equivalent to that given in the section has ever been noted at other nearby localities.

In Illinois the earlier investigators aimed to correlate the sections of the coal measures with the Kentucky and Indiana sections. Lesquereux was no doubt the first one to record the extensive development of this limestone formation in Illinois, the Curlew limestone being noted in a section at Shawneetown in his report on the coal fields of Illinois. He regarded this bed at Shawneetown as identical with the limestone in a section near Hollaway, in Henderson county, in Kentucky. In the same report the author mentions the following localities where the Curlew limestone was observed, "on the Kaskaskia river, two miles south of the town of Carlyle" and "at Joloffs old mill site, ten miles south of Carlyle."† In Macoupin county the Curlew limestone was observed in the vicinity of Carlinville.‡

There seems to be an error on the part of Lesquereux in the correlation of this limestone. In Kentucky his so-called Curlew limestone is not identical with Owen's Carthage limestone. The Carthage limestone occurs some 940 feet higher up in the "Connected Section of Upper and Lower Coal Measures of Kentucky."§ In Macoupin and Clinton counties, Illinois, the Curlew limestone is the equivalent of the Carthage limestone.

In his report on the Geology of Washington, Clinton and Jefferson counties,‖ Englemann characterizes quite fully the limestone as it is developed in these counties and calls it the Shoal Creek limestone, apparently because of its excellent exposures along this creek in Clinton county. In describing the Geology of Gallatin county,¶ Cox identified limestone near New Haven with "Owens Carthage limestone," and in a report on the Geology of Bond county,** Broadhead identified the limestone occurring along Locust Fork creek as the Shoal Creek limestone.

In a detailed generalized section of the coal measures of Illinois†† constructed by Worthen, the Shoal creek limestone was placed between coals number 9 and 10. Both the lithological and paleontological characters were briefly described and typical localities at which the formation is best exposed enumerated. In LaSalle county‡‡ the same author referred a limestone, number 3 in his section, of the river bluff in the neighborhood of Peru, to the Carlinville limestone.

*Indiana Geol Reconn. Report 1859-60, p. 310, 1862.
†Ill. Geol. Surv., vol. 1, p. 222, 1866.
‡Ill. Geol. Surv., vol. 1, p. 227, 1866.
§Kentucky Geol. Surv. vol. 3, pp. 18-23, 1857.
‖Ill. Geol. Surv., vol. 3, pp. 148, 159-164, 175, 220; 1868.
¶Ill. Geol. Surv., vol. 6, p. 212, 1875.
**Ill Geol. Surv., vol. 6, pp. 129 and 133, 1875.
††Ill. Geol. Surv., vol. 6, p. 3, 1875.
‡‡Ill. Geol. Surv., vol. 7, pp. 47 and 48. 1863.

The name Somerville has been used more recently by Fuller and Clapp in the "Patoka Folio"* for a limestone which is probably the equivalent of the Shoal Creek limestone.

## Known Distribution.

The most northern point at which a possible equivalent of the Shoal Creek limestone has been observed is at LaSalle. From this point its outcrops have been traced to the southeast, passing into Indiana a little north of the point where the Wabash river enters the State, and to the southwest, reaching their westernmost point at Carlinville in Macoupin county. From here they are found in a belt extending southeastward, reaching their most southern extension in Saline county. A few more localities are known in Gallatin and White counties.

These are approximately the boundaries of the Shoal Creek limestone as mapped by the former survey. In the detailed mapping now in progress some minor deviations from this outline will no doubt be found. Within these boundaries the limestone when present lies at some distance below the surface, ranging from less than 100 down to 700 feet. Exposures are limited to the bordering belt and are rarely met with, owing to the drift cover.

## Description of Exposures.

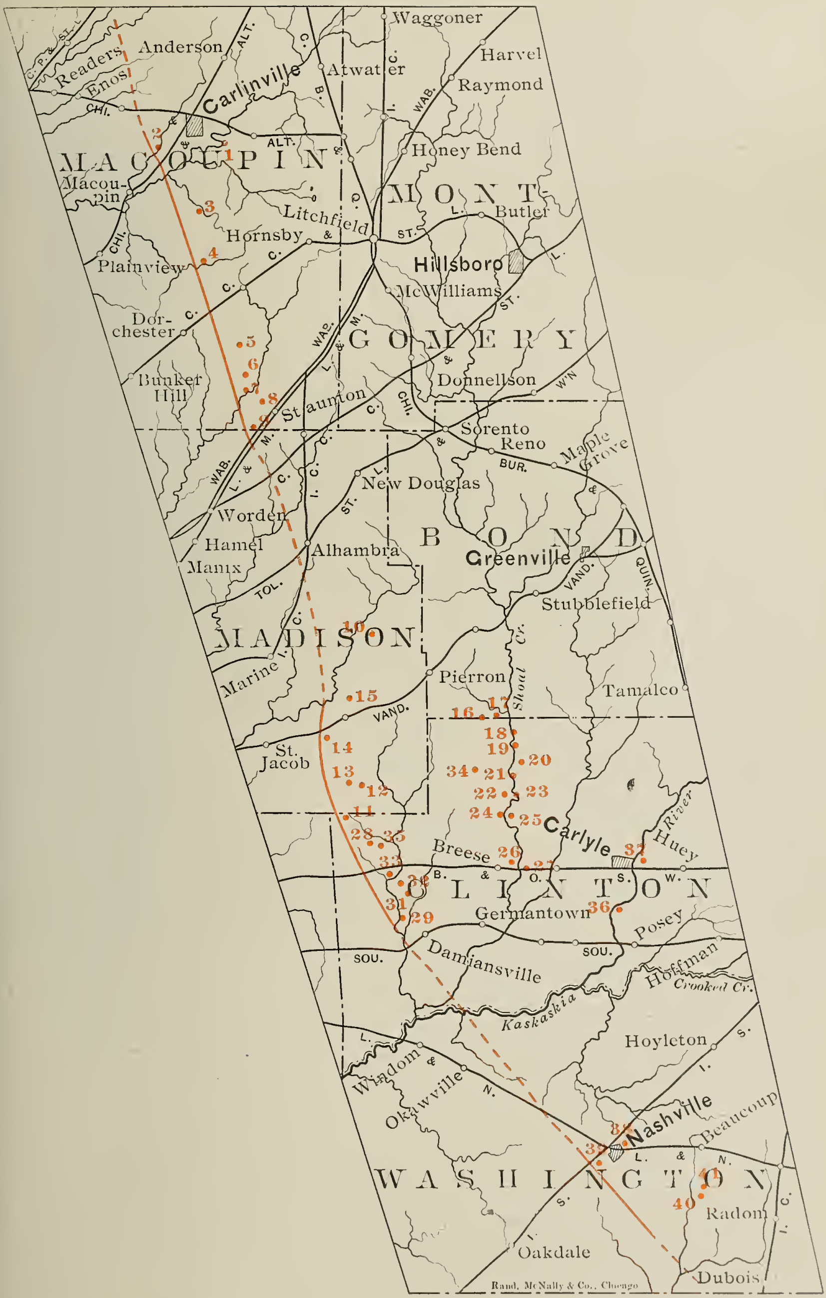
The data collected in Macoupin, Madison, Bond, Clinton and Washington counties, can best be presented in the form of a descriptive list of the localities where the rock was noted. (See map, plate 4.)

*Macoupin county*—1. The most northern exposure observed is located on the Walker farm in Macoupin creek in the northeast quarter of section 35, T. 10 N., R. VII W., where the following section was noted:

| | Feet. |
|---|---|
| 3. A chocolate colored, coarse grained limestone, in beds, one half to six inches in thickness. This limestone has a fauna abounding in Producti and Bellerophons. In examining the fossils the following were identified: *Productus longispinus*, *Productus punctatus*, *Productus cora*, *Productus nebraskensis*, *Productus semireticulatus*, *Bellerophon montfortanus*, *Bellerophon percarinatus*, *Bellerophon meekanus*, *Aviculopecten occidentale*, *Straparollus subquadrata*, *Chonetes variolata*, *Orthoceras rushense*, *Derbya crassa*, *Spirifer cameratus*, *Lophophyllum proliferum*, *Seminula argentea*, *Spiriferina kentuckiensis*, *Myalina*, sp. und., *Murchisonia*, sp. und..... | 3½ |
| 2. Grayish colored shales.......... | 10 |
| 1. A very hard, bluish gray limestone, occurring in seams varying from 3, 8 to 12 inches in thickness. On weathering the limestone turns brown, containing such fossils as *Seminula argentea*, *Reticularia perplexa*, *Productus longispinus*, *Hustedia mormoni*, *Pugnax uta*, *Dielasma boivedens*, *Ambocelia planoconvexa*, *Spirifer kentuckiensis*.......... | 2 |

2. Between three and a half and four miles west of the last locality, on Harrington creek in the northwest quarter of section 31, T. 9 N., R. VII W., the same limestone as number one of locality number one was observed. Its thickness is about 6 feet, and on fresh exposure has a bluish gray color, but

*U. S. G. S. Geol. Atlas of the U. S., Patoka Folio, No. 105, 1904.




Map showing distribution of Shoal Creek Limestone.

on weathering it turns brown. The beds vary in thickness from 6, 12 to 18 inches. Fossils are rather few in number and the most conspicuous form being a gasteropod, apparently a *Naticopsis*, which is associated with *Spirifer cameratus, Reticularia perplexa. Seminula argenea, Lophophyllum proliferum, and* an undetermined pelycypod.

3. On the east side of Spanish Needles creek, in the southwest corner of the northwest quarter section 21, T 9 N., R. VII W., the following section was observed:

| | | Feet. |
|---|---|---|
| 2. | A bluish gray limestone very hard, in beds 9, 12 and 18 inches in thickness, breaking into very irregular splintery pieces. It weathers to brown | 7 |
| 1. | Grayish shale with some bituminous partings | 3-4 |

4. In a small tributary to Spanish Needles creek, in the northwest quarter of section 28, T. 9 N., R. VII W., limestone and shale was observed in the same relation as in locality number three.

The Shoal Creek limestone can be traced along the greater part of Cahokia creek from its headwaters in section 36, T. 8 N., R. VII W., to section 25, T. 7 N., R. VII W.

5. Along the Cahokia creek east of Mount Glare, close to the center of section 36, T. 8 N., R. VII W., the following section appears:

| | | Feet. | Inches |
|---|---|---|---|
| 4. | Dark gray colored limestone, in beds varying from 6 to 18 inches in thickness, on weathering turning brown. This limestone assumes a pebbly appearance on weathering, and this is due to the unequal hardness of the different parts of the rock. The following fossils were observed: *Reticularia perplexa, Spirifer cameratus, pugnax uta, Hustedia mormoni, Seminula argentea, Lophophyllum proliferum, Productus longispinus*, and an undetermined gasteropod | 6-7 | |
| 3. | Dark shale | 1 | |
| 2. | Coaly seam | 1 | 10 |
| 1. | Dark colored shale | 4 | |

6. Further south along the same creek in the southeast quarter of section 12, T. 7 N., R. VII W., the same limestone was observed with a thickness approximately 7 feet.

7. In the northeast quarter of section 13, same township and range, along the same creek, limestone overlies a shale as below:

| | | Feet. |
|---|---|---|
| 2. | Grayish colored limestone, with an abundance of the corals *Lophophyllum proliferum* and *Campophyllum torquium* | 5 |
| 1. | Grayish colored shale | 7 |

8. Another locality is on a small tributary to Cahokia creek in the northeast quarter of section 19; in the northwest quarter of section 20, and in the south half of section 17, T. 7 N., R. VI W. The thickness of the limestone is about 5½ feet, dark gray in color, occurring in beds 6 and 12 inches in thickness. On weathering the limestone assumes a brown color. A few fossils were noted, especially a gasteropod, which has been observed frequently in other places besides *Productus longispinus, Reticularia perplexa* and *Seminula argentea.*

9. About one and a half mile west of Staunton, along the creek running north and south through the center of sections 24, 25 and 26, T. 7 N., R. VII N., limestone is fairly well exposed. In the southwest quarter of section 30, T. 7 N., R. VI W., a quarry has been worked in this limestone, and the following relations were observed:

| | Feet. |
|---|---|
| 4. Worthen's chocolate colored limestone. A very coarse-grained limestone, in places resembling a calcareous sandstone. It varies in color from yellow to brown. On weathering this rock has become very porous and readily disintegrates. It contains numerous fossils, such as different *Producti* and a number of *Bellerophons*. On account of the extensive weathering that the rock has suffered, the fossils are usually poorly preserved | 3-4 |
| 3. Grayish blue shale without fossils | 15 |
| 2. A bluish gray colored limestone, in seams varying in thickness from 9, 12, 18 and 24 inches. On weathering the limestone turns brown. | 6½ |
| 1. A grayish colored shale. A small seam about 3 inches in thickness immediately underneath the Shoal Creek limestone was very fossiliferous, containing a great number of *Chonetes* | 4 |

*Madison county*—10. The most conspicuous exposure of the Shoal Creek limestone observed in this county is to be found near the village of Saline, on A. J. Craft's place, in the northwest quarter of section 4, T. 4 N., R. V W., on Silver creek. The following section was noted in quarry operated by Mr. Craft:

| | Feet. |
|---|---|
| 4. Light colored shale calcareous | 2½ |
| 3. Dark gray limestone, rather fine-grained, tough and breaking into small irregular splinters. Containing fossils such as *Seminula argentea*, *Pugnax uta*, *Productas longispinus*, *Spirifer cameratus* and *Naticopsis altonensis* | 4½ |
| 2. A small seam of dark colored shale that contains a rather large number of fossils, especially a *Chonetes*, *Derbya crassa* and *Productus longispinus* | 1 |
| 1. A black slate, very stiff and with a great number of joints, containing no fossils | 2¼ |

11. In the creek near the south line of the southeast quarter of section 31, T. 3 N., R. V W., near by to the north the rock was formerly quarried.

12. A little to the west of the Buckeye school house in section 20, T. 3 N., R. V W.

13. In the bed of the main creek near the north line of the northeast quarter of section 19 the limestone is exposed for a distance of 10 rods or more. In a ravine joining this creek from the south in the northwest quarter of the same section it also appears in a face 6 feet high.

14. In the bed of the main creek, some rods northwest of the center of the northwest quarter of section 1, T. 3 N., R. VI W., were broken blocks somewhat disturbed.

15. About two miles north and one mile west of Highland the limestone is exposed in a creek. It here overlies a black carbonaceous slate.

*Bond county.*—16. East of the center of section 33, T. 4 N., R. IV W. undisturbed ledges of limestone overlie some black slate. under which is a two inch seam of impure coal. The ledges appear in the north bank of the main creek running from west to east through the section. Disturbed blocks of the limestone appear further up in the creek.

17. In the southwest corner of section 34, T. 4 N., R. IV W, the lower ledges of the limestone form the bed in the creek running north for a distance of some 150 yards. The overlying sandy shales were seen in the wagon road to the south. Slabs of black slate in the rubble indicate other exposures further up the creek. In the bank of the creek near the bridge in the center of the southwest quarter of section 35, T. 4 N., R. VI W, the limestone shows in ledges of considerable thickness.

*Clinton county.*—In the ravine running from west to east through the center of the south half of sections 2, T. 3 N., R. IV W, the limestone appears in several places, the greatest thickness noted is four feet. About two feet of the underlying black stiff slate was also seen, but no coal.

19. The same rock occurs again in the ravine running east through the northeast quarter of section 11,T. 3 N., R. IV W. In the west bank of Shoal creek at the ford near the east quarter post of the section shreds of the limestone were seen under the drift and overlying some 24 feet of sandy bluish shales, which has several bands or layers with concretion of iron carbonate. These are mostly flattened bodies about two inches and four inches wide.

20. Near the center of the north half of section 14, T. 3 N., R. IV W, in the south bank of the creek which runs east, the following section was noted:

| | Ft. | In. |
|---|---|---|
| 6. Limestone | 2 | |
| 5. Three layers of limestone measuring respectively 2, 3 and 4 inches in descending order | | 9 |
| 3. Seam of clay | | 1 |
| 2. Limestone | 2 | 8 |
| 1. Limestone in slabs apparently slightly displaced | | 3 |

The ledges at this place have a notable dip to the east which was estimated at no less than two feet in one hundred. The lower three feet of the rock exhibits the habit noted elsewhere of developing parting seams at intervals of about three inches. The rock has been quarried in a ravine some sixteen rods to the northwest of this exposure.

21. Near the east line of section 23, T. 3 N., R. IV W, the limestone was noted in the south bank of Shoal creek, where this crosses the east line of the section about one-third of a mile north of the northeast corner of the section. It lies at an elevation of about ten feet above the bottom of the creek.

22. In the north half of the northeast quarter of section 27, T. 3 N., R. IV W., the bed of the creek running east exposes the limestone for a distance of several rods. There is a thickness of about five feet. The weathering has brought out the quite uniform three-inch layers in the ledges, especially in the upper ones. The upper surfaces of these layers present a knotty appearance due to numerous irregular elevations of an inch or more, from six inches to a foot wide.

23. One-fourth of a mile north of the center of section 26, T. 3 N., R. IV W., two feet of limestone was again noted in the same creek as above.

24. In the north bank of the creek in the northeast corner of section 34, T. 3 N., R. IV W., the Timmerman quarry is located and this limestone has been quite extensively worked. The section is as follows:

| | Ft. | In. |
|---|---|---|
| 6. Limestone in three ledges measuring respectively from above downward 8, 12 and 12 inches. The following fossils were noted: *Aviculopecten occidentale*, *Seminula argentea* and a *Productus* | 2 | 8 |
| 5. Limestone in two ledges, upper 8 inches, lower 12 inches | 1 | 8 |
| 4. Dark clay shale | | 4 |
| 3. Limestone | | 9 |
| 2. Stony or indurated shale with crystals of selenite | | 5 |
| 1. Bluish gray sandy limestone weathering brown disposed to exhibit on weathering bedding seams about two and one-half inches apart | 4 | 3 |

25. Half a mile further south, in a ravine which joins this creek from the south, this rock has been quarried for a lime kiln. It is seen to overlie a black slate. This is in section 35 same township and range.

26. At the old mill site on the west bank of Shoal creek in the southeast quarter of section 11, T. 2 S., R. IV W., the following section was noted above the water during a rise in the creek:

| | Ft. | In. |
|---|---|---|
| 7. Limestone in one strong ledge | 2 | |
| 6. Blue clay shale | | 3 |
| 5. Limestone | | 3 |
| 4. Blue shale | | 3 |
| 3. Limestone with alternating clayey layers | | 6 |
| 2. Blue clay shale | | 4 |
| 1. Limestone | 2 | 6 |

Almost the entire outcrop shows seams from one-half to three inches apart. These always run in irregular curves up and down corresponding to inequalities on the surface of the slabs into which much of the rock is broken. A syringoporoid coral was noted in profusion in a block in the masonry of the old dam.

27. Near the southwest corner of section 13, T. 2 N., R. IV W., several feet of the limestone are to be seen in the bed of the creek near the wagon bridge close to the Breese pumping station.

28. One-fifth of a mile west of the northeast corner of section 8, T. 2 N., R. V W., Knaus quarry is located. The section shown in the quarry is as below:

| | Ft. | In. |
|---|---|---|
| 5. Marly soft shale or clay with many fossils | | 6 |
| 4. Limestone in three subequal ledges separated by marly and fossiliferous clay partings | 2 | |
| 3. Dark shale | | 6 |
| 2. Bluish gray compact limestone | 5 | 8 |
| 1. Bluish gray shale | | 2 |

29. In the west bank of Sugar creek in the southeast quarter of section 34, T. 2 N., R. V W., large blocks of limestone were seen in several places, and a short distance to the west, limestone has been blasted out of a well under some forty feet of drift.

31. In the bed of the creek running east and west through the north half of the northeast quarter of section 27, T. 2 N., R. V W.

32. A quarry has been worked on a small scale in a ravine south of the B. & O. S.-W. railroad near the west line of section 22, T. 2 N., R. V W.

33. Quarries have been worked on both sides of the main creek near the center of section 21, T. 2N., R. V W.

34. Large loose blocks of the Shoal creek limestone lie in the bed of the creek a little east of the center of the south line of section 17, T. 3 N. R. IV W.

35. North of the wagon bridge over the main creek near the center of the northwest quarter of section 9, T. 2 N., R. V W., the rock was also noted.

36. Southwest of Carlyle about two miles and a half, in the northeast quarter of section 35, on Stone Quarry creek, a quarry has been operated where the following section was observed:

| | Ft. | In. |
|---|---|---|
| 4. A grayish colored limestone, weathering brown, in seams 3 and 12 inches in thickness, containing a great number of crinoid stems | 3 | 4 |
| 3. Dark colored shale with crinoid stems and *Derbya crassa* | 6 | 12 |
| 2. Shoal creek limestone, gray color, very hard and breaking up into irregular splinters, in beds 6 and 18 inches thick, with a great abundance of *Productus longispinus* between bedding planes | 6 | 7 |
| 1. A very black slate, to bottom of creek | 3 | |

In the northwest quarter of section 35 in the same township and range limestone similar to number 4 of locality 36 was observed. Fossils are more abundant and a great number of a *Chonetes* and a *Productus* were noted. The limestone is more sandy and a great number of imbedded flakes of mica were observed. The total thickness amounted to about three feet.

37. In a ravine north of the cemetery north of Carlyle in section 18, T. 2 N., R. II W., a limestone similar to the above is observed with a thickness about four feet. The limestone is greatly weathered and showed the sandy appearance and contains flakes of mica. Fossils are rather abundant.

*Washington county.*—About one mile north of Nashville along the west side of the creek in the northwest quarter of the section 13, T. 2 S., R. III W., limestone has been quarried. It is approximately four and a half feet in thickness, bluish gray in color, very hard and containing *Reticularia perplexa*, *Productus longispinus*, *Seminula argentea*, and an undetermined gasteropod. Beneath the limestone, a grayish colored shale was observed about one foot in thickness containing many fossils such as a *Chonetes*, *Derbya crassa* and *Productus longispinus*.

39. A similar limestone has been quarried about two miles west of Nashville in section 22, T. 2 S., R. III W.

40. Along Beaucoup creek quarries have been worked in the Shoal creek limestone. On Mr. Merkles' place in the southwest quarter of section 34, T. 2 S., R. II W., the following section was noted:

| | Ft. | In. |
|---|---|---|
| 1. Bluish gray colored limestone. Very hard, breaking into irregular pieces and weathering brown. The following fossils were observed: *Productus longispinus*, *Spirifer cameratus*, *Pugnax uta*, *Reticularia perplexa*, *Seminula argentea and* an undetermined gasteropod ........................................ | 4 | 5 |
| 2. A very black slate to bottom of creek ........................ | 2 | |

In digging a well at Mr. Wm. Merkles' place it was observed that this slate had a thickness of four feet, below which a gray shale or "soapstone" some 25 feet in thickness is reported.

41. This same limestone was observed in the northeast quarter of section 34, T. 2 S., R. II W., and also along the creek crossing the east and west highway between section 23 and 26 same township and range.

## SUMMARY.

In the exposures that have been described, the following succession appears above and below the Shoal Creek limestone

5. Chocolate colored limestone, 4 feet.
4. Gray shales, 15 feet.
3. Shoal creek limestone, 7 feet.
2. Gray shales, 4 feet.
1. Black slate, 6 inches to 4 feet.

The topmost limestone (number 5) is coarse grained and brown in color. In some places it has the appearance of a sandstone, containing some quartz sand and flakes of mica. Fossils are numerous, but in most cases poorly preserved on account of its rapid disintegration on weathering.

The grayish colored shales (number 4) vary in different localities in both color and texture. Occasionally they contain bituminous partings. No fossils have been observed in their upper portion, but a few have been noted in the shale resting on the Shoal Creek limestone.

The Shoal Creek limestone (number 3) is generally bluish gray, compact, close textured, and very hard, breaking into irregular splintery pieces. On weathering it assumes a rusty color. It averages about seven feet in thickness. There are two features that are characteristic of this limestone, one a blotchy appearance, and another its tendency to weather into seams two and one-half or three inches in thickness.

It is interesting to note the relative abundance of the fossils in the Shoal Creek limestone. The fauna of this limestone excluding the shaly partings occurring between the different beds, is quite limited in forms. Only four fossils are abundant: *Productus longispinus, Reticularia perplexa, Seminula argentea* and a gasteropod, probably *Naticopsis altonensis,* usually found in the upper foot of this limestone in a poor state of preservation. Associated with these one occasionally finds *Hustedia mormoni and Pugnax uta.*

On comparing the fauna of number 5 of the above section, with that of the Shoal Creek limestone, one is impressed with the difference between the two. There are present in the upper rock an abundance of Producti such as *P. longispinus, P. punctatus, P. cora, P. nebraskensis, P. semireticulatus, and Bellerophon Meekanus,* and with these are a number of *Chonetes variolata* and *Spirifer cameratus.*

The grayish colored shales (number 2) varies in thickness from one to four feet. Fossils have been found in the upper three or four inches which lie in contact with the limestone. There is usually found a great abundance of *Chonetes mesoloba* and *Derbya crassa.*

The black slate (number 1) is cut up by joints which are usually five or six inches apart, and breaks readily into thin pieces along the lamination planes. Another peculiarity of this slate is that it contains some grayish white traversions resembling fucoid markings. (Plate 5.) These run parallel with the bedding planes and are from an eighth to more than half an inch in breadth and run variously in straight and sinuous courses through the slate. Their forms suggest that these may be tracks of animals which inhabited the mud which formed the slate.

There are a number of small stone quarries throughout this area, although none are worked on a large scale. No building stone is exported, and such quarries as these, merely supply the local demand for building stone and in one place for road material.

Fucoidal markings in black slate associated with the Shoal Creek limestone.

# CEMENT MAKING MATERIALS IN THE VICINITY OF LA SALLE.

(By Gilbert H. Cady.)

## Contents.

## INTRODUCTION.

Both Portland and natural cement are manufactured in the vicinity of LaSalle, Illinois. The deposite used for making natural cement is the Lower Magnesian limestone; the LaSalle limestone, and in some cases a carbonaceous shale immediately underlying it, are used in the manufacture of Portland cement.

*Natural cement materials*—A single deposit, containing within itself the necessary chemical ingredients in such proportions as to afford a natural mixture suitable for a good hydraulic cement, while less eagerly sought after since the enormous and rapid growth of the Portland cement industry, is still of considerable economic interest. Furthermore, the Utica cement companies, some of which have operated in the locality nearly one-half a century, enjoyed a considerable local reputation in this and neighboring states previous to any large production of Portland cement in this country. There still continues to be a sufficient demand for this cement to warrant the two existing companies manufacturing 1500 to 2000 barrels a day. With the added interest that this is the single locality in the State where natural hydraulic cement is made, we have sufficient reason for devoting some attention to the character and extent of the deposits at this place.

The Lower Magnesian limestone outcrops in a one hundred-foot cliff forming the north bluff of the Illinois river for a distance of about two miles from a point on the west called Split Rock, one mile and a half east of LaSalle, to a point on the east within one-half mile of the town of Utica. (See plate 6.) Likewise it underlies the flood-plain of the Illinois river to the south of the cliff, and is found at the base of the bluff on the south side of the river. About midway along the cliff is the gorge of Pecumsaugum creek. Up this gorge the limestone continues for nearly a mile, where it ends abruptly. The upper surface of this limestone is an erosion surface, not a bedding plane surface, so that an unconformity exists between it and overlying strata, and the extent of its outcrop is everywhere determined by the slope of this eroded surface.

This limestone is the oldest geological formation in the State, lying at the base of the Ordovician series or at the top of the Cambrian. Exclusive of less extensive outcrops in Ogle and one in Calhoun county, this is its only occurrence in the State. As in all the other cases where it is found, it is here brought to the surface by structural deformation, in this case the LaSalle anticline. The axis of this anticline extends from Wisconsin southeast through the neighborhood


Portland Cement Rock
▲ Portland Cement Plant
Natural Cement Rock
△ Natural Cement Plant

Map showing distribution of cement plants and materials near LaSalle.

Portland plants.
1. German-American Portland Cement Co.
2. Chicago Portland Cement Co.
3. Marquette Portland Cement Co.

Natural cement.
1. Illinois Hydraulic Cement Mfg. Co.
2. Utica Hydraulic Cement Co.
3. Hydraulic cement (plant not in operation.)

of Freeport, is to be observed between Oregon and Dixon, where it brings to the surface the Trenton limestone, to be used by the Sandusky Portland Cement Company of Dixon as a source of cement material, and passes just east of LaSalle, continuing across the Illinois river in the direction of the Illinois field. It is usually a "simple low arch or anticlinal swell," but in this locality the western limb of the anticline is much shorter and has a stronger dip to the west, so that within the one-half mile lying west of the Lower Magnesian limestone, 400 feet of coal measure strata and 75 to 100 feet of St. Peters sandstone are brought to the surface, dipping west at angles varying from 30 degrees in the case of the sandstone to 5 degrees or 10 degrees in the case of the coal measures. The dipping beds of St. Peters sandstone lie in unconformity upon the sloping irregular surface of the Lower Magnesian limestone, and so cut across the nearly horizontal beds of the limestone. The strata of the limestone seem not to have been affected along the same axis of folding as the overlying formation, but dip rather uniformly in three directions, east, west and south, from a point near the mouth of Pecumsaugum creek. The upper surface attains its height further west or near the main axis of folding, and is relatively flat or slightly sloping toward the east at the point of maximum uplift of the formation. Thus, the center of deformation of the limestone, which seems to form the core of the anticline, lies on the east side of the main axis of folding.

The beds of natural cement material are of course affected by the deformation. The lowest bed of the Lower Magnesium strata is exposed near the Pecumsaugum gorge. This is the site of an old cement plant recently abandoned to other uses. Here the two beds of natural cement deposits are both above ground. The lower bed occurs at the base of the cliff, and the upper one about 20 feet above. Each of these beds is from six to eight feet in thickness. These beds dip toward the east at such a rate that one mile farther east at the Illinois Hydraulic Cement Manufacturing Company's plant the upper level is about 4 feet above the base of the cliff, and the lower mine is 15 to 20 feet below. Here the lower horizon is said to be 12 or 14 feet in thickness. The upper bed continues to be from 6 to 8 feet thick. Still farther east and a little south, the Utica Hydraulic Cement Co. quarry the upper horizon out of the floor of the valley, and the lower level is reached by a vertical shaft.

The structural irregularities affect the methods of mining, but not the character of the deposit, which remains relatively constant throughout the district. The limestone is a fine grained silicious to argillaceous limestone, light gray to buff in color, having an irregular laminated appearance due to the alternation of thin hard and soft layers. The rock weathers to a rather smooth surface and is quite soft.

There is no distinguishing characteristic to separate the productive horizons from the non-productive. The determination is largely a matter of chemical analysis and experimental testing. Analyses of the rock used by the Illinois Hydraulic Cement Mfg. Co. show the following percentages of ingredients:

ANALYSES OF THE UTICA NATURAL CEMENT ROCK.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Silica | 29.84 | 27.70 | 26.46 | 11.89 | 27.60 | 15.02 | 14.42 |
| Iron | 1.52 | 1.41 | 1.36 | 1.35 | .80 | 8.20 | 11.34 |
| Alumina | 3.36 | 2.33 | 3.39 | 11.61 | 10.60 | ........ | ........ |
| Lime | 30.17 | 29.94 | 30.30 | 29.51 | 33.04 | 25.40 | 26.12 |
| Magnesia | 20.69 | 20.01 | 20.81 | 20.38 | 17.26 | 12.50 | 9.82 |
| Volatile matter | 10.24 | 16.03 | 13.38 | ........ | ........ | 38.54 | 38.70 |
| | 95.82 | 97.52 | 95.70 | ........ | ........ | 99.66 | 100.50 |

1, 2, 3, C. B. Lihme, Analyst. 4, 5, Quoted from Eckels: "Cements, Limes, Plasters." 6. Upper bed. Analyzed by State Geological Survey. 7. Lower bed. Analyzed by State Geological Survey.

The two companies operating at present in this locality are the Illinois Hydraulic Cement Manufacturing Company, and the Utica Hydraulic Cement Co. Each plant has two kilns, each kiln having a daily capacity of about 400 barrels.

Farther north in this district there are two other occurrences of Lower Magnesian limestone; an irregular outcrop extending at intervals for a mile above the junction of the Tomahawk creek and the Little Vermilion river, and a less extensive outcrop along the Little Vermilion river in Section 22, Range 1 East, Township 34 North. Both of these outcrops occur along the axis of the LaSalle anticline. The strata are nearly horizontal and lithologically the rock resembles the limestone near Utica. Whether or not this is a natural cement rock is not determined.

*Portland Cement materials*—The manufacture of Portland Cement in Illinois from natural deposits of cement material is largely centered in the LaSalle district. The three plants located there manufactured during the past year a product valued at 2,600,000 dollars. The present capacity of the three plants is about 6,000 barrels per day, and the almost completed extension of one plant will increase that capacity to about 8,000 barrels. The source of the cement material is, as has been stated, the LaSalle limestone, and in two cases the carbonaceous shale immediately underlying the limestone.

The LaSalle limestone, like the Lower Magnesian limestone, is geographically best described in reference to the LaSalle anticline. It occurs along the west flank of the fold. As it is the highest formation it is usually found outcropping along a line where the folding is first perceived, and so is parallel to the main axis of the anticline.

Two other features of the geography bearing close relationship to the outcropping limestone and the anticline, are the Vermilion and Little Vermilion rivers. From Lowell to the Illinois river, the Vermilion river runs in a very meandering course near the edges of the limestone, sometimes parallel and again transverse to the main line of the folding. The irregularities of the river from Lowell to its mouth gives three excellent exposures of the anticlinal structure, north and south of Deer Park and on both sides of the river, and again east of Bailey's Falls along what is known as the "great bend."

North of the Illinois river the Little Vermilion river flowing from the north, encounters the limestone ledge on its west bluff about 4 miles

north of LaSalle, where the strata are dipping toward the west. The river runs southwest, parallel to the general direction of folding for about 2½ miles, with the limestone ledge occurring on the west bluff. It turns and runs southwest and then into the limestone belt. The anticlinal structure appears on both bluffs at this place, and a practically horizontal limestone ledge forms the walls of the gorge to the Illinois river bluff.

The limestone also outcrops to some extent along the bluffs of the Illinois river. On the north bluff, east of the mouth of the Little Vermillion river it continues for about one mile, when it is cut off by the upland surface. West of the Little Vermilion river the city of LaSalle is situated upon the top of the limestone, which continues as a conspicuous feature of the cliff to a point between LaSalle and Peru. On the south bluff, west of the Illinois Central Railroad, the limestone is not typical. The extent of the outcrops of the typical limestone confines the formation to a narrow belt extending along the Vermilion river to a point a little south of Bailey's Falls, and to a corresponding narrow belt extending about five miles along the Little Vermilion river.

The character of the limestone renders it a very conspicuous feature of these gorges. Because of the relative hardness, it usually forms a perpendicular ledge from fifteen to thirty feet in height near the top of the gorge. This is especially true along the Vermilion river. The limestone is less prominent north of the gorge of the Little Vermilion river, probably because the strata are not horizontal. In appearance the rock varies from a blue gray to a light cream color. If fresh, the stone is compact, with rather straight fractures. Where weathered it presents a fragmentary appearance, and sometimes, especially the lower horizon, is thin bedded. Long continued weathering brings out a difference in hardness in the rock. It is seen to be divided into two well defined horizons, the upper of which is the harder and so overhangs the lower. Where water runs over the rock, as at Bailey's Falls, the upper ledge forms the brink of the falls, projecting over the lower horizon.

Where the limestone outcrops along the anticline upon the upland, there is, in one case at least, a small "hog back" or hill. This is crossed, on the road running west from LaSalle to Peru, just about one mile out from LaSalle, where the road turns north. Here is the site of some small quarries and a lime kiln or two. This limestone hill can be traced very easily north northwest to the bluff of the Little Vermilion and south southeast to the bluff of the Illinois river. What would be a corresponding outcrop on the upland south of the Illinois river, running from the river bluff to the gorge of the Vermilion is completely concealed by superficial deposits. The strike is estimated from the outcrop along the Illinois and Vermilion rivers and the general direction of the anticline. The strike of the limestone along the bluff above Deer Park station is easily traced.

The stratigraphy of the limestone is fairly simple. Where outcropping it forms the top of the Coal Measure series, being at LaSalle about 400 feet above the base of the group of which it is a member. This

distance varies about ten feet each way over the district, becoming, as we would expect, somewhat greater toward the south. In thickness the formation varies from twenty to thirty feet. It is divided into two main beds, the upper one varying from five to fifteen feet in thickness, depending largely upon the amount of erosion undergone. The lower bed varies from six to sixteen feet in thickness. The division line between the two beds is a calcareous shale occurring at different heights above the base of the limestone and varying in thickness from eight inches to three and one-half feet.

There are two horizons of fossils, part of the fossils being confined to certain horizons. The upper fossil zone occurs in the upper part of the higher limestone belt. They are more likely to be found where the rock attains its maximum thickness. Following is a list of the conspicuous fossils of this zone: *Spirifer cameratus, Productus cora, P. costatus, P. semireticulatus* and *P. nebraskensis.*

A good collecting ground for these fossils is the small quarry on the electric road, about one mile east of LaSalle. There are good spemens to be found likewise along the Little Vermilion river north of LaSalle. The lower fossil zone is in close proximity to the layer of shale. As this is near the horizon most commonly exposed these fossils are found in nearly every outcrop. The old quarry of the Chicago Portland Cement Co. on the west side of the Vermilion river is a source of many good specimens. Some of the characteristic fossils are: *Productus longispinus, Meekella striatocostata, Spirifer kentuckiensis, Spirifer cameratus, Lophyllum proliferum.* The small brachiopod *Seminula argentea* is very common throughout the formation. Some very good specimens of the nautiloid group have been found in the limestones.

The difference in hardness suggested as existing between the upper and lower horizons because of the different rates of weathering is due to the presence of a large amount of argillaceous material in the lower bed. The especial problem of the chemists of the three cement plants is that of controlling the mix so as to keep the silica and alumina or the clay proportion constant. Not only is there argillaceous material present in the lower bed, but there is a constant variation in the amount present, which necessitates constant readjustment of the mix. This percentage of clay seems to vary from east to west, becoming greater toward the west.

Likewise the difference in thickness of the middle shale bed in different parts of the field controls materially the character of the deposits used by the three companies. Two of the plants are able to use the limestone from top to bottom as limestone, obtaining the clay from other sources. The other plant uses the limestone as limestone, while the middle shale bed serves as the source of the clay. Sometimes it is found necessary at this plant to reject this clay because of the high percentage of argillaceous material in the bed of the limestone below, and at other times there is an almost perfect natural mixture.

The floor of the quarries and mines is a hard layer of limestone about two feet thick, whose plane of parting seems to place it structurally with the underlying stratum. Beneath the floor rock is a bed of

carbonaceous shale grading into a blue limey clay, each bed containing a narrow seam of coal an inch or two thick. In two of the plants this shale and clay is the source of silica and alumina for the cement. In these cases the bed of the limestone at the top of the shale is considered as a part of it and the analyses made accordingly. There is some hint that this method is causing some difficulty because of the varying per cent of the calcareous content thus introduced.

The percentage of magnesia is in all cases below the danger point, 5 per cent. Upon this low per cent of magnesia rests much of the success of the LaSalle Portland Cement industry.

The accompanying analyses will show more definitely the character of the limestone and clay in different parts of the LaSalle limestone area:

ANALYSES OF THE LA SALLE LIMESTONE.

| $SiO_2$ | $Fe_2O_3$ and $Al_2O_3$ | CaO | MgO | Volatile Matter. | Source of the Samples Analyzed. |
|---|---|---|---|---|---|
| 6.06 | 3.92 | 49.46 | .91 | 39.06 | Chicago P. C. Co |
| 8.20 | 1.30 | 49.37 | .85 | 39.72 | Marquette P. C. Co |
| 7.54 | 3.43 | 45.57 | 4.36 | 39.57 | German-American P. C. Co |
| 5.06 | 2.52 | 48.29 | 3.66 | 41.05 | ..do |
| 13.89 | 2.61 | 45.91 | 1.00 | 36.82 | ..do.. |
| 5.43 | 1.43 | 52.02 | 1.11 | 40.24 | ..do.. |
| 6.72 | 5.92 | 47.84 | .66 | 40.20 | N. W. ¼ Sec. 11, T. 33 N., R. 1 E |
| 11.10 | 7.84 | 43.46 | 1.16 | 37.38 | S. E. ¼ Sec. 34, T. 34 N., R. 1 E |
| 4.92 | 3.08 | 50.52 | .89 | 41.36 | Near LaSalle, upper bed |
| 22.26 | 6.86 | 36.62 | 1.91 | 33.28 | Near LaSalle, uper part of lower bed |
| 17.76 | 9.56 | 36.64 | 2.42 | 34.36 | Near LaSalle, lower part of lower bed. |
| 4.43 | 2.86 | 51.32 | .59 | 41.92 | Chicago P. C. Co., upper bed |
| 9.62 | 5.56 | 46.08 | .74 | 39.16 | Chicago P. C. Co., lower bed |
| 2.66 | 1.96 | 52.32 | .58 | 38.54 | Bailey's Falls, upper bed |
| 15.24 | 7.58 | 41.54 | 1.14 | 38.80 | Bailey's Falls, lower bed |
| 2.88 | 2.24 | 51 78 | .69 | 42.06 | Section 14, T. 33 N., R. 1 E., upper bed |
| 8.78 | 4.76 | 46.08 | 1.96 | 39.26 | Sec. 14, T. 43 N., R. 1 E., upper part of lower bed |
| 10.34 | 4.40 | 45.58 | 1.38 | 37.88 | Slc. 14, T. 33 N., R. 1 E., lower part of lower bed |
| 1.98 | 1.56 | 53.32 | .75 | 42.66 | Marquette P. C. Co., roof rock |
| 7.94 | 4.80 | 48.02 | .68 | 39.48 | Marquette P. C. Co., upper part of lower bed |
| 8.24 | 3.40 | 47.72 | 1.31 | 38.90 | Marquette P. C. Co., lower part of lower bed |

The first six analyses are taken from Eckel: "Cement, Limes, and Plasters." The remaining fifteen are analyses by the State survey of samples collected by the members.

ANALYSES OF CLAYS USED BY THE LASALLE CEMENT COMPANIES.

| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | Volatile matter. | |
|---|---|---|---|---|---|---|
| 53.12 | 20.60 | 4.09 | 4.02 | 2.24 | 13.70 | Chicago P. C. Co |
| 54.30 | 19.33 | 5.57 | 3.29 | 2.57 | ............ | Marquette P. C. Co |
| 53.48 | 22.36 | | 7.64 | 1.78 | ............ | Chicago P. C. Co |

The first two analyses are from Eckel: "Cements, Limes and Plasters," the last analyses by the State Geological Survey.

Local opinion as to the occurrence of the limestone further west seems to favor an extensive glacial erosion, resulting in the removal of the most of the limestone strata. An examination of the strata which occur at the horizon of the limestone along the Illinois river bluff west of the mouth of the Vermilion has led the writer to a different opinion. West of the Vermilion the final exposure of typical limestone occurs in a small ravine running north and south about the middle of section 26, range 1 east, township 33 north. From that point west there is a gradual change from calcareous to argillaceous material and structure, with the result that the formation that occurs in the bluff just south of the end of the LaSalle bridge is an outcrop showing nearly 30 feet, 12 feet at least being of shale. Part of the shale has abundant calcareous concretion, which in the next ravine east or toward the Vermilion river becomes even more prevalent and the rock becomes more like limestone. At the same time one of the clay beds above has in it thin lenses of limestone, very much like the LaSalle limestone. West of the Marquette Cement plant where the Vermilion bends farthest to the west there is likewise a slightly noticeable change in the lithological composition of the rock, with an indication of a substitution of clay for limestone.

The change in the lithological character of the rock is not so noticeable on the north side of the Illinois river, but was first observed in a small gully between Peru and LaSalle.

Toward the west the two narrow limestone ledges, the upper becoming rather silicious and the lower crinoidal and pure, varying from one and one-half to four feet in thickness are rather constant and correspond to the top and base of the LaSalle limestone. Between these two ledges are varying thicknesses of blue or black shale, sometimes calcareous.

A rough estimate of the total area of the limestone would be about twelve square miles, or so much as would be contained between the eastern edge and a line drawn parallel to the anticlinal axis one-half mile west of the most westerly outcrop of the limestone along the Vermilion river.

The three companies operating in the district are the Chicago Portland Cement Co., with a daily capacity of about 1,500 barrels, to be shortly increased to 4,500. The Marquette Portland Cement Co., with a capacity of 2,500 barrels. The German American Portland Cement Co., with a capacity of 1,800 barrels. The Chicago P. C. Co., and the German American P. C. Co. quarry the limestone, while the Marquette P. C. Co., obtain it by mining.

# STATISTICS AND DIRECTORY OF THE CLAY INDUSTRIES OF ILLINOIS.

(By Edwin F. Lines.)

## Statistics.

Since 1905 the State Geological Survey has coöperated with the U. S. Geological Survey in obtaining reports of the amount and value of the mineral products of Illinois. The following table reproduced from The Mineral Production of Illinois in 1905* gives by counties, the value of the clay and clay products produced in that year.

*Value of Clay and Clay Products in 1906.*

| Counties. | Brick. | Sewer pipe and drain tile. | Pottery. | Raw clay. | Number of producers reporting. |
|---|---|---|---|---|---|
| Adams | $ 64‘124 | | | | 9 |
| Alexander | | | | | 2 |
| Bond | | | | | 1 |
| Boone | | | | | 2 |
| Brown | | | | | 1 |
| Bureau | 16,080 | $ 21,300 | | | 9 |
| Calhoun | 37,731 | | | $ 3,350 | 4 |
| Carroll | | | | | 2 |
| Cass | 15,655 | 3,500 | | | |
| Champaign | 59,970 | 12,100 | | | 6 |
| Christian | 30,875 | 18,700 | | | 11 |
| Clark | 19,100 | 1,000 | | | 5 |
| Clay | 3,975 | | | | 5 |
| Clinton | 6,610 | 120 | | | 5 |
| Coles | 11,000 | 14,500 | | | 4 |
| Cook | 4,874,682 | 143,505 | $ 29,469 | 15 | 34 |
| Crawford | 11,212 | 4,188 | | | 3 |
| Cumberland | | | | | 1 |
| DeKalb | 13,854 | 22,717 | | | 7 |
| DeWitt | | | | | 1 |
| Edgar | 69,779 | 18,439 | | | 15 |
| Fayette | 119,184 | 14,913 | | | 23 |
| Ford | | | | | 1 |
| Fulton | | | | | 2 |
| Gallatin | 7,090 | 171,828 | | | 9 |
| Greene | | | 170,500 | 46,350 | 6 |
| Grundy | | | | | 2 |
| Hamilton | 59,187 | 12,923 | | | 17 |
| Henry | | | | | 1 |
| Iroquois | 8,554 | 45,778 | | | 10 |
| Jackson | 52,735 | 874 | | | 11 |
| Kankakee | 1,109,998 | 156,280 | | | 13 |
| Lake | | | | | 2 |
| LaSalle | 740,706 | 229,998 | 6,000 | 39,332 | 36 |
| Macon | 52,884 | 6,250 | | | 4 |
| Macoupin | 15,258 | 500 | | | 5 |
| Madison | 399,442 | 45,400 | | | 16 |
| Marion | 12,750 | 200 | | | 1 |

*State Geological Survey, Circular No. 2.

*Value of Clay and Clay Products in 1906*—Concluded.

| Counties. | Brick. | Sewer pipe and drain tile. | Pottery. | Raw clay. | Number of producers reporting. |
|---|---|---|---|---|---|
| Marshall | ............ | ............ | ............ | ............ | 1 |
| Massac | $ 4,400 | ............ | $ 42,300 | $ 1,245 | 4 |
| McDonough | 25,290 | $215,254 | 356,300 | 26,524 | 16 |
| McHenry | ............ | ............ | ............ | ............ | 2 |
| McLean | 54,350 | 12,450 | ............ | ............ | 5 |
| Menard | 14,319 | 5,670 | ............ | ............ | 5 |
| Mercer | 9,100 | 55,820 | ............ | ............ | 3 |
| Monroe | ............ | ............ | ............ | ............ | 1 |
| Montgomery | 30,654 | 15,315 | ............ | ............ | 8 |
| Morgan | 9,700 | 18,750 | ............ | ............ | 4 |
| Moultrie | 5,150 | 14,800 | ............ | ............ | 4 |
| Ogle | ............ | ............ | ............ | ............ | 2 |
| Peoria | 76,938 | 1,000 | ............ | ............ | 10 |
| Perry | ............ | ............ | ............ | ............ | 1 |
| Piatt | 2,240 | 17,110 | ............ | ............ | 4 |
| Pike | 8,630 | 270 | ............ | ............ | 3 |
| Pulaski | ............ | ............ | ............ | ............ | 1 |
| Randolph | 22,553 | ............ | ............ | ............ | 4 |
| Richland | ............ | ............ | ............ | ............ | 2 |
| *Rock Island | 127,447 | 18,650 | ............ | 2,425 | 16 |
| Saline | 18,890 | 3,000 | ............ | ............ | 5 |
| Sangamon | 208,732 | 10,194 | ............ | ............ | 13 |
| Schuyler | 8,480 | 9,744 | ............ | ............ | 4 |
| Scott | 2,800 | ............ | 200 | 1,020 | 3 |
| Shelby | 12,950 | 13,180 | ............ | ............ | 7 |
| Stark | 5,900 | 2,000 | ............ | ............ | 3 |
| St. Clair | 404,175 | ............ | 2,154 | ............ | 9 |
| Stephenson | ............ | ............ | ............ | ............ | 2 |
| Tazewell | 64,377 | 25,950 | 28,000 | ............ | 7 |
| Union | 1,232 | ............ | ............ | 7,561 | 3 |
| Vermilion | 423,273 | 23,300 | ............ | ............ | 10 |
| Wabash | ............ | ............ | ............ | ............ | 2 |
| Warren | 20,855 | 253,751 | 333,280 | ............ | 7 |
| Washington | ............ | ............ | ............ | ............ | 2 |
| Wayne | 2,601 | 4,700 | ............ | ............ | 4 |
| White | 10,982 | 17,543 | ............ | ............ | 6 |
| Whiteside | ............ | ............ | ............ | ............ | 1 |
| Will | 42,799 | 54,069 | ............ | ............ | 7 |
| Williamson | 26,825 | ............ | 10,000 | 362 | 4 |
| Winnebago | 15,342 | ............ | ............ | ............ | 5 |
| Woodford | 12,317 | 9,619 | ............ | ............ | 3 |
| †Other counties | 411,104 | 45,646 | 22,700 | 3,088 | ............ |
| Totals | $9,896,840 | $1,772,798 | $982,903 | $131,272 | 498 |

* Includes sand-lime brick.
† Includes Alexander, Bond, Boon, Brown, Carroll, Cumberland, DeWitt, Ford, Fulton, Grundy, Henry, Lake, Marshall, McHenry, Monroe, Ogle, Perry, Pulaski, Richland, Stephenson, Wabash, Washington, Whiteside.

Preliminary figures for 1907 indicate a total value of clay and clay products for that year of $13,351,362 made up as follows:

| | |
|---|---|
| Brick | $ 9,957,791 00 |
| Sewer pipe and tile | 2,283,702 00 |
| Pottery | 1,004,160 00 |
| Raw clay | 105,703 00 |
| | $13,357,362 00 |

The table below which is taken from the statistics of the clay working industries in the United States compiled by the U. S. Geological Survey shows the progress of the various branches of the industry in Illinois for the five years between 1902 and 1906, inclusive:

| Product. | 1902 | 1903 | 1904 | 1905 | 1906 |
|---|---|---|---|---|---|
| Brick: | | | | | |
| Common— | | | | | |
| Quantity | 1,023,681,000 | 1,015,541,000 | 999,310,000 | 1,125,024,000 | 1,195,210,000 |
| Value | $5,131,621 | $5,388,589 | $5,167,165 | $6,259,232 | $5,719,906 |
| Average per M | $5.01 | $5.31 | $5.17 | $5.56 | $4.79 |
| Vitrified— | | | | | |
| Quantity | 91,116,000 | 96,568,000 | 121,073,000 | 90,563,000 | 122,227,000 |
| Value | $839,784 | $1,015,710 | $1,234,703 | $973,247 | $1,306,476 |
| Average per M | $9.22 | $10.52 | $10 20 | $10.75 | $10.69 |
| Front— | | | | | |
| Quantity | 20,943,000 | 25,122,000 | 21,299,000 | 30,447,000 | 30,022,000 |
| Value | $240,466 | $274,723 | $251,762 | $348,354 | $341,298 |
| Average per M | $11.48 | $10.93 | $11.82 | $11.44 | $11.37 |
| Fancy or ornam'nt'l, value | $11,893 | $12,927 | $11,733 | $13,567 | $11,635 |
| Fire, value | $199,048 | $233,106 | $217,008 | $176,692 | $236.032 |
| Drain tile, value | $698,783 | $892,807 | $1,002,463 | $1,051,852 | $1,051,588 |
| Sewer pipe, value | $360,149 | $532,858 | $550,344 | $580,538 | $587,805 |
| Architectural terra cotta, value | $1,000,765 | $1,198,477 | (a) | (a) | (a) |
| Fireproofing, value | $358,015 | $335,838 | $324,264 | $323,550 | $409,171 |
| Tile (not drain) value | $257,049 | $283,426 | $194,471 | (a) | (a) |
| Pottery: | | | | | |
| Earthenware and stoneware, value | $602,708 | $694,770 | $801,946 | $889,857 | $935,193 |
| Yellow and Rockingham ware, value | (a) | (a) | (a) | (a) | |
| C. C. and white granite ware, value | $56,256 | $168,363 | .............. | .............. | (a) |
| Semivitreous porcelain ware, value | (b) | (b) | .............. | .............. | |
| Miscellaneous, value | $130,303 | $159,203 | $1,021,588 | $1,744.897 | $2,034,077 |
| Total value | $9,881,840 | $11,190,797 | $10,777,447 | $12,361.786 | $11,634,181 |
| Number of operating firms reporting | 515 | 502 | 492 | 469 | 466 |
| Rank of State | 4 | 4 | 4 | 5 | 5 |

*a* Included in miscellaneous.
*b* Included in C. C. and white granite ware.

## DIRECTORY.

An important part of the equipment of a geological survey is an accurate and complete directory of the mineral industries. Such a directory is necessary both for obtaining reports of production and as a means of keeping producers informed of the latest progress in their own field.

In October, 1907, a systematic effort was begun to compile an accurate directory of clay workers for Illinois. A post card bearing a return address was mailed to each known producer with the request that he give the correct firm name and the products of the plant. With the exception of about twenty firms who were reported indirectly cards were returned from all but four of those to whom the requests were sent. From the information thus obtained the directory has been compiled. It has already been used by the State Geological Survey as a means of distributing bulletins relating to clay and by the University of Illinois as a mailing list for notices of the clay workers' institute held annually by the department of ceramics.

In order to meet a demand for knowledge of the location of clay mines and of the producers of different classes of clay ware the directory is herewith published. It is possible that some firms who have not been reported to the survey are omitted. Notifications of such omissions will be much appreciated.

DIRECTORY OF THE CLAY INDUSTRIES OF ILLINOIS.

Raw Clay.

| Firm Name. | Town. | County. |
|---|---|---|
| Argillo Works | Carbon Cliff | Rock Island |
| Baird, O. & Sons | Colchester | McDonough |
| Big Four Wilmington Coal Co. (Office, 293 Dearborn St., Chicago | Coal City | Grundy |
| Behimiller, Mrs. John | Park Ridge | Cook |
| *Butterfield, Lester L. | Colchester | McDonough |
| Calhoun Brick & Clay Co. (Office, Benoit Bldg., St. Louis, Mo | Golden Eagle | Calhoun |
| Chocago Retort & Brick Co. (Office, 45th & LaSalle Sts., Chicago | Ottawa | LaSalle |
| Dawson, Wiliam | Deer Park | LaSalle |
| Goodman, Thos. B. (Office, Cobden) | Kaolin | Union |
| Hicks, Clay Co. | Drake | Greene |
| Hodge, Green | Metropolis | Massac |
| Illinois Fire Proofing Co | Grafton | Jersey |
| *McLaughlin Mining Co | Alsey | Scott |
| Macomb Illinois Clay Products Co | Macomb | McDonough |
| Myers, B. F | Colchester | McDonough |
| Reynolds, Geo. M | Utica | LaSalle |
| Rockton Moulding Sand Co. (Office, Freeport) | Rockton | Winnebago |
| Russell Clay Works | Macomb | McDonough |
| Utica Fire Brick Co | Utica | LaSalle |
| Wilmington Star Mining Co | Coal City | Grundy |

*Not operated in 1907.

Building Brick, Hollow Blocks and Drain Tile.

| | | |
|---|---|---|
| Abbott, W. K | Quincy | Adams |
| Abraham, Jacob, & Son | Moline | Rock Island |
| Ade, J. G | Pana | Christian |
| Albion Vitrified Brick Co | Albion | Edwards |
| Aledo Brick & Tile Works | Aledo | Mercer |
| Alsey Brick & Tile Co | Alsey | Scott |
| Alton Paving, Building & Fire Brick Co. | Alton | Madison |
| Ammann & Co | Decatur | Macon |
| American Brick Co | Chicago | Cook |
| American Clay Products Co (Office, 145 LaSalle St., Chicago.) | Roanoke | Woodford |
| Anderson, Charles | Petersburg | Menard |
| Anderson Brothers | Taylorville | Christian |
| Arbogast, S. C., & Sons | Farmer City | DeWitt |
| Argillo Works | Carbon Cliff | Rock Island |
| Astoria Brick Works | Astoria | Fulton |
| Atkinson, Olaff | South Rock Island | Rock Island |
| Auburn Brick, Tile & Cement Co | Auburn | Sangamon |
| Avon Milling & Mfg. Co | Avon | Fulton |
| Back Brick Co | Chicago | Cook |
| Backus & Sholes | Hampshire | Kane |
| Baird & Collins | Peotone | Will |
| Baldridge, I. S | Stonington | Christian |
| Barr, Andrew | Urbana | Champaign |
| Baker Brothers | Chestnut | Logan |
| Barr Clay Co | Streator | LaSalle |
| Bartelme, P. M | Springfield | Sangamon |
| Batis & Wessler | Arenzville | Cass |
| Beale, J. M., & Co | Pawpaw | Lee |
| Beall, Chas. E., & Sons | Paris | Edgar |
| Bell, James W | Clinton | DeWitt |
| Belleville Brick Co | Belleville | St. Clair |
| Belting, Theo | Mattoon | Coles |

## *Directory of the Clay Industries of Illinois*—Continued.

### *Building Brick, Hollow Blocks and Drain Tile*—Continued.

| Firm Name. | Town. | County. |
|---|---|---|
| Belvidere Brick Co | Belvidere | Boone |
| Bement Brick Co | Bement | Piatt |
| Benld Brick & Tile Co | Benld | Macoupin |
| Benton Brick Co | Benton | Franklin |
| Bible, J. C. | Louisville | Clay |
| Billings, H. E. (Office, Macomb.) | Neponset | Bureau |
| Billings Brothers | Noble | Richland |
| Black Hawk Clay Mfg. Co (Office, Davenport, Ia.) | Sears | Rock Island |
| Bird & Pratt | Roseville | Warren |
| Blake, E. L. | Grand Tower | Jackson |
| Bloomington Pressed Brick Co | Bloomington | McLean |
| Zander, Gus | Rushville | Schuyler |
| *Brackensick, John | Quincy | Adams |
| Bradfield & Pollitt | Indianola | Vermilion |
| Brown, H. P | Palmer | Christian |
| Buck Brothers | Morris | Grundy |
| Buckley Brothers | Winchester | Scott |
| Builders Brick Co | Chicago | Cook |
| Burckhardt, Jacob | Waterloo | Monroe |
| Burke, Alexander | Chicago | Cook |
| Burnett, C. A | St. Peter | Fayette |
| Bush, R., & Son | Mt. Sterling | Brown |
| Calhoun Brick & Clay Co (Office, Benoit Bldg., St. Louis, Mo.) | Golden Eagle | Calhoun |
| Calumet Brick Co | Chicago | Cook |
| Camp, George W | Texas City | Saline |
| Carbondale Pressed Brick Co | Carbondale | Jackson |
| Carpenter, Mrs. M. C | Altamont | Effingham |
| Carter, F. R | East Peoria | Tazewell |
| Carterville Brick & Tile Co | Carterville | Williamson |
| Cashmore, Jonathan | Wadsworth | Lake |
| Chamberlin, John W., Brick Co | Litchfield | Montgomery |
| Charleston Tile & Brick Co | Charleston | Coles |
| Chicago Brick Co | Chicago | Cook |
| Chilton, C. H | Barry | Pike |
| Churchill, Horatio | Buda | Bureau |
| Cisne Brick Co | Cisne | Wayne |
| Citizens Coal Mining Co | Lincoln | Logan |
| Cleary, T. W (Office, Rockford.) | Guilford | JoDaviess |
| Cole, J. B., & Co | Owaneco | Christian |
| Columbia Clay Works | Columbia | Monroe |
| Compton, Ezra | Carmi | White |
| Comstock, C. H | Ashkum | Iroquois |
| Consolidated Electric & Supply Co | Assumption | Christian |
| Condon, James | Mazon | Grundy |
| Cook, Harvey V | Odin | Marion |
| Corbett, Thomas | Alton | Madison |
| Correll & Cox | Trimble | Crawford |
| Corrington Brothers | Moweaqua | Shelby |
| Cowgill, C. C., & Co | Brocton | Edgar |
| Craycroft, Benj., & Son | Vandalia | Fayette |
| Creston Tile Co | Creston | Ogle |
| Cromister, J. C | Athens | Menard |
| Crum, Frank M | Palmyra | Macoupin |
| Cuba Brick Co | Cuba | Fulton |
| Curtis, S. E | Edgewood | Effingham |
| Curtis, The Alonzo, Brick Co | Grant Park | Kankakee |
| Dallas City Brick & Tile Co | Dallas City | Hancock |
| Dalton, James | Peoria | Peoria |
| Damhorst Brothers | Quincy | Adams |
| Danville Brick Co | Danville | Vermilion |
| Dawson, J. S | Ivesdale | Champaign |
| Dawson Brick & Tile Co | Springfield | Sangamon |
| Decatur Brick Co | Decatur | Macon |
| Decker Brothers | New Haven | Gallatin |
| Dettman, Henry J | Danville | Vermilion |
| DeWitte, Powell & Zink | Murphysboro | Jackson |
| Deymann, George | Teutopolis | Effingham |

*Not operated in 1907.

## *Directory of the Clay Industries of Illinois*—Continued.

*Building Brick, Hollow Blocks and Drain Tile*—Continued.

| Firm Name. | Town. | County. |
|---|---|---|
| Doerfler & Jackson | Waverly | Morgan |
| Duddleston, David M., & Son | Stewardson | Shelby |
| Eagle Lake Ice & Tile Works | Beecher | Will |
| Earlville Brick & Tile Mfg. Co | Earlville | LaSalle |
| East Peoria Brick Co | Peoria | Peoria |
| Eastern Illinois Brick Co | Beecher | Will |
| Edwards Vitrified Brick & Sewer Pipe Co* | Albion | Edwards |
| Eiker, Charles F.* | Chicago Heights | Cook |
| Elgin Brick & Tile Co (Office, Elgin.) | McQueen | Kane |
| Eller, Peter | Carlyle | Clinton |
| Elmwood Brick & Tile Co | Elmwood | Peoria |
| Ericson & Skiles | Virginia | Cass |
| Ewing, C. C | Browns | Edwards |
| Ewing, Stephen C | Paris | Edgar |
| Fairfield Brick & Tile Works | Fairfield | Wayne |
| Farnam, Lindsay | Pawnee | Sangamon |
| Farnam, D. A., & Co | Zenobia | Sangamon |
| Fenstermaker, B. F | Ellsworth | McLean |
| Ferguson, Hugh | Redmon | Edgar |
| Ferguson, Thomas, & Co | Cairo | Alexander |
| Fisher, W. O | Basco | Hancock |
| Fleigle, Philip | Morrisonville | Christian |
| Ford, J. B., Lumber Co | Harrisburg | Saline |
| Fordyce, Sherman | Table Grove | Fulton |
| Foulds, Joseph M | Carthage | Hancock |
| Fox, William | Peoria | Peoria |
| Frazee, Oscar | Moweaqua | Shelby |
| Frisch, H. P | Mt. Pulaski | Logan |
| Fulrath, William R | Savanna | Carroll |
| Gausmann & Mueller | Belleville | St. Clair |
| Giles, Albert E | Peoria | Peoria |
| Gillette Brick & Tile Co (Office, Chemical Bldg., St. Louis, Mo.) | Woodhull | Henry |
| Glenview Brick Co | Glenview | Cook |
| Glimpse, William, & Son | Deer Creek | Tazewell |
| Goodwin, Thomas | Chillicothe | Peoria |
| Goodwin Brothers | Minonk | Woodford |
| Graham, John W | South Rock Island | Rock Island |
| Green, Hiram | Anna | Union |
| Greenville Lumber Co | Greenville | Bond |
| Greenwood, Joseph | Sunfield | Perry |
| Griffith & Boyer | Carmi | White |
| Griggs, S. B | Marion | Williamson |
| Habel, Thomas A | Henning | Vermilion |
| Haeger, D. H., Estate of (Office, Dundee.) | Dundee and Gilberts | Kane |
| Hainline, James M., Sons & Co | Blandinsville | McDonough |
| Hamer, J. Wallace | Armstrong | Vermilion |
| Hansen, Charles | Bradford | Stark |
| Hansen Brothers | Princeton | Bureau |
| Harbaugh, C. A | Mendota | LaSalle |
| Harms Brick Co (Office, 1543 Wolfram St., Chicago.) | Glenview | Cook |
| Harrison, John H | Mineral | Bureau |
| Hass, J. T., & Son | Coal Valley | Rock Island |
| Heafer, Edgar M., Tile Co | Bloomington | McLean |
| Heckard, Martin, & Sons | Canton | Fulton |
| Heinmann, Gus J., & Co | Chicago | Cook |
| Heller, Newton, & Co | Table Grove | Fulton |
| Hellrung, Henry A | Liberty Prairie | Madison |
| Herbst, John F | Bunker Hill | Macoupin |
| Hess, Emil J | Mendota | LaSalle |
| Hilgeman, E. H | Belmont | Wabash |
| Hill, Edward | Frederick | Schuyler |
| Hillsboro Brick & Tile Co | Hillsboro | Montgomery |
| Hinckley Tile Works | Hinckley | DeKalb |
| Hocking & Walker | Golden Gate | Wayne |
| Hogue, J. W | Mattoon | Coles |

*Not yet in operation (Dec., 1907.)

## *Directory of the Clay Industries of Illinois*—Continued.

### *Building Brick, Hollow Blocks and Drain Tile*—Continued.

| Firm Name. | Town. | County. |
|---|---|---|
| Holland Brick Co | South Moline | Rock Island |
| Holler, Ross | Marshall | Clark |
| House of Correction | Chicago | Cook |
| House of Correction | Peoria | Peoria |
| Hugenberer, Husmann & Hecker | Tallula | Menard |
| Hull, John L | Cambridge | Henry |
| Huseman, Augustus | Pittsfield | Pike |
| Hutmacher, Nick | Dieterich | Effingham |
| Hutsonville Brick & Tile Co | Hutsonville | Crawford |
| Hydraulic Press Brick Co (Office, Missouri Trust Bldg., St. Louis, Mo.) | Collinsville | Madison |
| Illinois Brick Co (Office, Chamber of Commerce Bldg., Chicago.) | Bernice | Cook |
| | Blue Island | Cook |
| | Chicago | Cook |
| | Doltons | Cook |
| | Pullman | Cook |
| | Shermerville | Cook |
| Illinois Brick & Tile Co | Litchfield | Montgomery |
| Illinois Fire Proofing Co | Grafton | Jersey |
| Ittner, Anthony, Brick Co | Belleville | St. Clair |
| Jansen & Zoeller | Pekin | Tazewell |
| Johnson, David F., & Sons | Pinkstaff | Lawrence |
| Johnston, P. M., Brick Works | St. Elmo | Fayette |
| Joliet Mound Drain Tile Co | Joliet | Will |
| Jones, James H | Metcalf | Edgar |
| Joute, Theo | Mattoon | Coles |
| Jordan, John H | Gibson City | Ford |
| Judy, F. D | Mackinaw | Tazewell |
| Junkens, A. E (Office, Homer). | Ogden | Champaign |
| Kankakee Tile & Brick Co | Kankakee | Kankakee |
| Karstens, August | Moline | Rock Island |
| Keller, Gus C., & Co | Willow Springs | Cook |
| Kelley, T. L | Hazel Dell | Cumberland |
| Kemnitz & Schneider (Office, 1258 Oakdale Ave., Chicago.) | Niles | Cook |
| Kessler, Conrad | Ingraham | Clay |
| King, Moses | Colchester | McDonough |
| Fitner, F. H | Woodson | Morgan |
| Floess Brick Co | Belleville | St. Clair |
| Kloppenburg, H. T | Springfield | Sangamon |
| Krooss, Henry | Lamoille | Bureau |
| LaBahn, John P (Office, 1724 Gary Place, Chicago.) | Evanston | Cook |
| LaBahn Brick Co (Office, 92 LaSalle St., Chicago.) | Lansing | Cook |
| Lake View Brick Co | Chicago | Cook |
| Lambert, H., & Son | Beaverville | Iroquois |
| Lamport, A. C., & Co | Dahlgren | Hamilton |
| LaSalle Pressed Brick Co | LaSalle | LaSalle |
| Latham Brick & Tile Co | Latham | Logan |
| Lincoln Mining Co., Lessee | Lincoln | Logan |
| Lincoln Park Coal & Brick Co | Springfield | Sangamon |
| Little, George H | Littleton | Schuyler |
| Lutter Brick Co | Glenview | Cook |
| Loda Brick & Tile Co | Loda | Iroquois |
| Lodge, William F | Monticello | Piatt |
| Lombard Brick & Tile Co | Lombard | DuPage |
| Loy, D. O | Wataga | Knox |
| | Atkinson | Henry |
| Loyd, S. B | Farmersville | Montgomery |
| Lundvall, Charles A | Rockford | Winnebago |
| Lyon, W. E., & Co | Carthage | Hancock |
| McAfee, A. T., & Son | Nokomis | Montgomery |
| McCarthy Brothers | Pana | Christian |
| McClure, Lee | Colchester | McDonough |
| McClure, G. W., & Son | Kappa | Woodford |
| McCoy & Son | Little York | Warren |
| McGinness, J. M | Effingham | Effingham |
| McGregor, James H., Brick Co | Bloomington | McLean |
| McIntire, William, & Son | Equality | Gallatin |

## *Directory of the Clay Industries of Illinois*—Continued.

*Building Brick, Hollow Blocks and Drain Tile*—Continued.

| Firm Name. | Town. | County. |
|---|---|---|
| McKnight, Hugh B | Ramsey | Fayette |
| McLaren, C. C | Summum | Fulton |
| McMullen, A. G | Kewanee | Henry |
| McNeil Pressed Brick Co (Office, Chemical Bldg., St. Louis, Mo.) | Newborn | Jersey |
| McShane, Richard | Lostant | LaSalle |
| Mamer Brothers | Campus | Livingston |
| Manteno Brick & Tile Co | Manteno | Kankakee |
| Marion Pressed Brick Co | Marion | Williamson |
| Marquis, Daniel M | Milford | Iroquois |
| Martin, J. F | Arthur | Douglas |
| Martin, L. H | Dwight | Livingston |
| Martin & Parr | Astoria | Fulton |
| Martz Brothers | Shelbyville | Shelby |
| Marxer, Joseph | Millstadt | St. Clair |
| Mauerman, F.* | Bartonville | Peoria |
| Mead, S. R., & Son | Springerton | White |
| Meersman, John B | South Moline | Rock Island |
| Meier, Fred | Monmouth | Warren |
| Melley, Jacob, & Brother | Red Bud | Randolph |
| Meyer, E. E | Crescent City | Iroquois |
| Meyer, H. C | Beardstown | Cass |
| Miller, Amos S | Vermont | Fulton |
| Miller, Louis | Highland | Madison |
| Millsdale Pressed Brick Co (Office, 140 Dearborn St., Chicago.) | Hillsdale | Will |
| Monmouth Brick & Tile Co | Monmouth | Warren |
| Monmouth Mining & Mfg. Co | Monmouth | Warren |
| Moody, John, & Sons | Carlinville | Macoupin |
| Moody, R. B | DeLand | Piatt |
| Mooney Brothers | Highland Park | Lake |
| Mt. Carmel Dry Press Brick Co | Mt. Carmel | Wabash |
| Mt. Vernon Press Brick Co | Mt. Vernon | Jefferson |
| Mowbray & Lowes | Geneseo | Henry |
| Munson Brothers | Capron | Boone |
| Murphy & Lorimer Brick Co | Chicago | Cook |
| Napersville Drain Tile & Brick Works | Napersville | DuPage |
| Nashville Press Brick Co | Nashville | Washington |
| National Brick Co (Office, 84 LaSalle St., Chicago.) | Chicago; Chicago Heights | Cook |
| National Pressed Brick Co | Mascoutah | St. Clair |
| Niemeyer, Fred | New Memphis | Clinton |
| Northwestern Clay Mfg. Co | Griffin | Mercer |
| Oberschelp, H. G | Princeton | Bureau |
| Oberschelp, H. H | Ohio | Bureau |
| Oberschelp & Son | Manlius | Bureau |
| Oblong Mfg. Co | Oblong | Crawford |
| Oland Brick & Tile Co | Witt | Montgomery |
| Olney Paving Brick & Tile Co | Olney | Richland |
| Onarga Brick & Tile Works | Onarga | Iroquois |
| Ortman, Frank A | Cullom | Livingston |
| Osborne, Frank | Illiopolis | Sangamon |
| Patten, Frank C | Hinckley | DeKalb |
| Patten Brothers | Rankin | Iroquois |
| Patton, Henry C | Flanagan | Livingston |
| Paul & Henderson | Virginia | Cass |
| Paulsen, Hans | South Rock Island | Rock Island |
| Paxton Brick and Tile Co | Paxton | Ford |
| Peoria Tile Works | Peoria | Peoria |
| Peters, Fred J | Thomasboro | Champaign |
| Peterson, S | Benson | Woodford |
| Pioneer Brick & Tile Works | Earlville | LaSalle |
| Piper, F. E | Sullivan | Moultrie |
| Pihrman & Stockheker | Quincy | Adams |
| Plainfield Tile Co | Plainfield | Will |
| Plumb Brothers Brick & Tile Co (Office, Carthage.) | Burnside | Hancock |
| Polo Brick & Tile Works | Polo | Ogle |
| Pratt, H. H., Lumber & Brick Co | Carrier Mills | Saline |

*Not in operation in 1907.

## *Directory of the Clay Industries of Illinois*—Continued.

### *Building Brick, Hollow Blocks and Drain Tile*—Continued.

| Firm Name. | Town. | County. |
|---|---|---|
| Price & Gunning | Industry | McDonough |
| Prutsman, Alford | Milford | Iroquois |
| Rabe, John P | Homewood | Cook |
| Ramsey, Lawrence | Crossville | White |
| Randal, Albert | Bartonville | Peoria |
| Rantoul Brick & Tile Co | Rantoul | Champaign |
| Rapp Brothers | Morton | Tazewell |
| Rardin Brothers | Westfield | Clark |
| Ray Tile Works | Ray | Schuyler |
| Reddick Brick & Tile Co | Reddick | Kankakee |
| Record, A. M | Lafayette | Stark |
| Redecker, B. & H | Rock Island | Rock Island |
| Remley, Joseph & Son | Enfield | White |
| Rhodes Brothers & Co | Mt. Carroll | Carroll |
| Richards Brick Co | Edwardsville | Madison |
| Richmond, George H | South Rock Island | Rock Island |
| Riley & Heafer | Bloomington | McLean |
| Roberts Brick & Tile Co | Roberts | Ford |
| Roller, George B | Canton | Fulton |
| Rundles & Son | Clinton | DeWitt |
| Russell, Albert G | Westfield | Clark |
| Sackriter, George | Mahomet | Champaign |
| St. Anne Brick & Tile Co | St. Anne | Kankakee |
| St. Louis Press Brick Co (Office, St. Louis, Mo.) | Glen Carbon | Madison |
| Salvesan Brothers | Petersburg | Menard |
| Schernekau Bhothers | West Salem | Edwards |
| Schlecter Brothers | Okawville | Washington |
| Schneider, G. W | Marissa | St. Clair |
| Schroeppel Pressed Brick Co | Collinsville | Madison |
| Seaton Brick & Tile Co | Seaton | Mercer |
| Sehy, John | Ashland | Cass |
| Selby, John W | Tower Hill | Shelby |
| Selley, T. S | Danville | Vermilion |
| Seward Brothers | Mason City | Mason |
| Shale Brick & Tile Works | Carlinville | Macoupin |
| Sharon Brick & Coal Co | Georgetown | Vermilion |
| Shaw, Josiah E | Joliet | Will |
| Shaw, Silas, Brick Co | Joliet | Will |
| Shaw, White & Co | Vandalia | Fayette |
| Sheldon Brick Co (Office, Champaign.) | Urbana | Champaign |
| Sikes Brick Co | Hampton | Rock Island |
| Smith, Caleb | McLeansboro | Hamilton |
| Smith, John | Tiskilwa | Bureau |
| Smith & White | Harvel | Montgomery |
| Shavely, L. C | Martinsville | Clark |
| Snell, A | Tice | Menard |
| Snell, William H | Blue Mound | Macon |
| Solfisburg, Chris., Sons | Aurora | Kane |
| Southard, M. E | Woodland | Iroquois |
| Southern Illinois Penitentiary | Menard | Randolph |
| Speigler, B. P | Buckley | Iroquois |
| Spilker, C., & Sons | Quincy | Adams |
| Springfield Paving Brick Co | Springfield | Sangamon |
| Standard Brick Co | Belleville | St. Clair |
| Steep, Ed | Seneca | LaSalle |
| Stewardson, C. W | Strasburg | Shelby |
| Stonger, Edward, & Brother | Pana | Christian |
| Streator Clay Mfg. Co., The | Streator | LaSalle |
| Streator Paving Brick Co | Streator | LaSalle |
| Stroot, John H | Quincy | Adams |
| Stukee, Mrs. Charles A | Geneseo | Henry |
| Sundrup, August | Bartelson | Clinton |
| Superior Brick Co | Genet | Winnebago |
| Sweet, C. R | Canton | Fulton |
| Swift Terra Cotta, Brick & Tile Co. | Ottawa | LaSalle |
| Tarbox, A. & E | Yorkville | Kendall |
| Taylor, James C | Hidalgo | Jasper |
| Tendick, William | Jacksonville | Morgan |

## *Directory of the Clay Industries of Illinois*—Continued.

### *Building Brick, Hollow Blocks and Drain Tile*—Concluded.

| Firm Name. | Town. | County. |
|---|---|---|
| Tiernam, P. H | Macomb | McDonough |
| Tilbury, Oliver | Towanda | McLean |
| Tilbury, C | Delavan | Tazewell |
| Tilley, J. Sanford | Tower Hill | Shelby |
| Todd, Charles K | LaHarpe | Hancock |
| Troy Pressed Brick Co | Troy | Madison |
| Trunk, Frank, & Son | Freeport | Stephenson |
| Turnbo, John L | Metropolis | Massac |
| Twist, R. S | Rochester | Sangamon |
| Underwood Pressed Brick Co | Springfield | Sangamon |
| Utica Fire Brick Co (Office, Hartford Bldg., Chicago.) | Utica | LaSalle |
| Vandeveer, C. W | Edinburg | Christian |
| Wagner, J. F | Princeton | Bureau |
| Walnut Hill Pressed Brick Co | Walnut Hill | Marion |
| Walter, George J | Chatsworth | Livingston |
| Walters, Adolph | Mason City | Mason |
| Walters, John W | Wyoming | Stark |
| Warner, D. D | Mt. Auburn | Christian |
| Watts, Joseph | Newton | Jasper |
| Waverly Brick & Tile Co | Waverly | Moran |
| Weaver, Joel, & Son | Casey | Clark |
| Weidler, Chris | Mt. Olive | Macoupin |
| Wenona Tile & Brick Works | Wenona | Marshall |
| West, Elias A | Omaha | Gallatin |
| West-Gregg Brick Co | Eldorado | Saline |
| West Canton Paving Brick Co | Canton | Fulton |
| Western Brick Co | Danville | Vermilion |
| Wheatcroft, William G | Grayville | White |
| Wheeler, Julius H | Marseilles | LaSalle |
| White Hall Sewer Pipe & Stoneware Co | White Hall | Greene |
| Wilcox, John | McLean | McLean |
| Wild, J. W | Gilman | Iroquois |
| Willis, Z. P., & Son | Ullin | Pulaski |
| Winter, I. S., & Sons | Wadsworth | Lake |
| Wisconsin Lime & Cement Co | Dolton | Cook |
| Wise & Fisherbuck (Office, Upland, Indiana.) | Bushnell | McDonough |
| Witts & Witts | Sullivan | Moultrie |
| Witwer, R. W | Kinmundy | Marion |
| Yeakel Brothers | Waynesville | DeWitt |
| Yoke, S. R | Ft. Erie | Wayne |
| Zander, Gus | Rushville | Schuyler |
| Zander, John A | Industry | McDonough |
| Zerr, Lawrence | Stewardson | Shelby |
| Zion Building & Mfg. Association | Zion City | Lake |

### Fire Proofing.

| | | |
|---|---|---|
| Eiker, Charles F.* | Chicago Heights | Cook |
| Illinois Fire Proofing Co | Grafton | Jersey |
| Monmouth Brick & Tile Co | Monmouth | Warren |
| Illinois Terra Cotta Lumber Co (Office, The Rookery, Chicago.) | Pullman | Cook |
| Northwestern Clay Mfg. Co | Griffin | Mercer |

*Operation not yet begun (Dec., 1907.)

## *Directory of the Clay Industries of Illinois*—Continued.

### Fire Brick.

| Firm Name. | Town. | County. |
|---|---|---|
| Argillo Works | Carbon Cliff | Rock Island |
| Avon Milling & Mfg. Co | Avon | Fulton |
| Calhoun Brick & Clay Co (Office, Benoit Bldg., St. Louis, Mo.) | Golden Eagle | Calhoun |
| Chicago Retort & Fire Brick Co | Chicago | Cook |
| | Ottawa | LaSalle |
| Hill, Edward | Frederick | Schuyler |
| Hillsdale Pressed Brick Co (Office, 140 Dearborn St., Chicago.) | Millsdale | Will |
| National Fire Proofing Co | Ottawa | LaSalle |
| (Main office, Fulton Bldg., Pittsburgh, Pa.) | Twin Bluffs | LaSalle |
| Western Fire Brick Co | Granite City | Madison |

### Paving Brick.

| | | |
|---|---|---|
| Abingdon Paving Brick & Tile Co | Abingdon | Knox |
| Alton Paving, Building & Fire Brick Co. | Alton | Madison |
| Banner Clay Works | Edwardsville | Madison |
| Barr Clay Co | Streator | LaSalle |
| Carter, F. R | East Peoria | Tazewell |
| Dawson Brick & Tile Co | Springfield | Sangamon |
| Gem City Paving Brick Co | Quincy | Adams |
| Hill, Edward | Frederick | Schuyler |
| King, Moses | Colchester | McDonough |
| Miller, Louis | Highland | Madison |
| Nashville Press Brick Co | Nashville | Washington |
| Purington Paving Brick Co | Galesburg | Knox |
| Springfield Paving Brick Co | Springfield | Sangamon |
| Streator Paving Brick Co | Streator | LaSalle |
| West Canton Paving Brick Co | Canton | Fulton |
| West-Gregg Brick Co | Eldorado | Saline |

### Sewer Pipe.

| | | |
|---|---|---|
| Columbia Clay Works | Columbia | Monroe |
| Macomb Sewer Pipe Co | Macomb | McDonough |
| Monmouth Mining & Mfg. Co | Monmouth | Warren |
| Northwestern Clay Mfg. Co | Griffin | Mercer |
| Stoneware Pipe Co., The | East Alton | Madison |
| Streator Clay Mfg. Co., The | Streator | LaSalle |
| White Hall Sewer Pipe & Stoneware Co | White Hall | Greene |

### Earthenware.

| | | |
|---|---|---|
| Holland Brothers | Carbon Cliff | Rock Island |
| Hrudka, John | Chicago | Cook |
| Keller, George, & Son | Chicago | Cook |
| Klipfel, H. F | Chicago | Cook |
| Kohr, A. F | Chicago | Cook |
| Lowell Pottery Co | Lowell | LaSalle |
| Zidelskii, Leo | Norwood Park | Cook |

## *Directory of the Clay Industries of Illinois*—Concluded.

### Stoneware

| Firm Name. | Town. | County. |
|---|---|---|
| Buckeye Pottery Co. | Macomb | McDonough |
| Ebey, O. O. | Winchester | Scott |
| Lowell Pottery Co. (Office, Tonica.) | Lowell | LaSalle |
| Ripley Pottery Co. | Ripley | Brown |
| Roodhouse Novelty Pottery Co. | Roodhouse | Greene |
| Shelton Pottery Co. | Metropolis | Massac |
| Stalrup, L. P. | Metropolis | Massac |
| Truka, A. K.* | Chicago | Cook |
| Western Stoneware Co. | White Hall<br>Monmouth<br>Macomb | McDonough |
| White Hall Pottery Works | White Hall | Greene |
| White Hall Sewer Pipe & Stoneware Co. | White Hall | Greene |

### Art Pottery.

| | | |
|---|---|---|
| Gates Potteries, The | Terra Cotta | McHenry |
| Crossware Pottery (Office, Grant Park.) | Chicago | Cook |
| Duschek, Emanuel, & Son | Elsdon | Cook |
| Norse Pottery Co. | Rockford | Winnebago |
| Webb, Judson T. | Chicago | Cook |

### Terra Cotta.

| | | |
|---|---|---|
| American Terra Cotta & Ceramic Co. (Office, Chamber of Commerce Bldg., Chicago.) | Terra Cotta | McHenry |
| Northwestern Terra Cotta Company | Chicago | Cook |

### Miscellaneous.

| | | |
|---|---|---|
| Alhambra Ceramic Works (Ceramic specialties.) | Chicago | Cook |
| American Carbon & Battery Co. (Electrical and hardware porcelain.) | East St. Louis | St. Clair |
| Illinois Mosaic Tile Co. (Floor tile.) | Chicago | Cook |
| Ludowici-Celandon Co. (Roofing tile.) | Chicago Heights | Cook |
| Rapp Bros. (Rockingham and yellow ware.) | Morton | Tazewell |
| Rockton Moulding Sand Co. Cupola clay.) | Rockton | Winnebago |
| Starck, P. M. (Clay pipes.) | Fulton | Whiteside |
| Tiffany Enameled Brick Co. (Office, Chamber of Commerce Bldg., Chicago.) (Enameled brick and tile.) | Momence | Kankakee |

*Shut down in 1907.

# EXPERIMENTS ON THE AMORPHOUS SILICA OF SOUTHERN ILLINOIS.

## Preliminary Report.

(By T. R. Ernest.)

There have been many inquiries as to possible uses of the material making up the numerous silica deposits of southern Illinois. For several years silica in various forms has been shipped from this region, the output being used for various polishing purposes, for paint mixtures, pipe covering and other purposes. The demand for silica for such uses, however, must remain relative small, in proportion to the extent of the deposits. It would be a matter of very considerable interest if the great quantities of material found there could be made available as for example, in some form of structural material. It was with this in mind that a series of investigations was begun under the direction of Professor S. W. Parr, of the University of Illinois for the purpose of studying the various chemical and physical properties of mixtures with lime, sand, and other substances. The mixtures were, of course, to be of various compositions and treated by various processes.

The first suggestion that presented itself was the possibility of forming a silicate of lime after the manner of the reaction taking place in the manufacture of sand-lime brick. Here a small per cent of slaked lime is mixed with sand and the material in brick form is subjected to the heat of a steam chamber at over 100 pounds pressure. A superficial reaction between the surfaces of the sand granules and the lime results in a bond which gives a fairly good texture to the mass. An effort was made, therefore, to determine how completely the minute amorphous particles of silica of these deposits would enter into a similar reaction to produce a homogeneous mass of silicate of lime.

It is already known that the grinding of a part of the sand that is to enter into the composition of sand lime brick adds materially to the value of the product. The finely ground sand seems to form with the lime, a larger percentage of cementing material and this unites more efficiently the larger particles of sand grains or other massive particles. In a similar manner, a mixture of lime and silica could be used to form a binding material or matrix for the coarser material and thus supplant or possibly improve upon the sand lime brick process. The aim of our experiments was to find, if possible, the best proportions for such a mixture.

The experiments thus far have been on samples of bricks made with a large percentage of lime. We hoped to be able to work out, if possible, the exact chemical composition of the compound that forms

between lime and silica in the hardening cylinder of the sand lime process, and, if such a thing were not attainable, to show that no definite compound results.

Numerous test samples have been made, ranging in lime content from 40 to 60 per cent and accompanied by physical tests and chemical analyses.

*Physical Tests*—The crushing strength of all samples was good, as indicated in the following table.

TABLE NO. 1.

CRUSHING STRENGTH.

| No. of Sample. | Percentage of lime used. | Pressure in molding. | Crushing strength per square inch. |
|---|---|---|---|
| 2 | 48 | 9,200 | 7,000 |
| 3 | 48 | 5,000 | 6,500 |
| 8 | 40 | 5,000 | 5,720 |
| 9 | 40 | 10,000 | 6,695 |
| 10 | 40 | 15,000 | ........................ |
| 11 | 50 | 5,000 | 5,915 |
| 12 | 50 | 10,000 | 7,100 |
| 13 | 50 | 15,000 | 6,720 |
| 14 | 60 | 5,000 | 4,145 |
| 15 | 60 | 10,000 | 5,900 |
| 16 | 60 | 10,000 | 6,520 |

The absorption test shown by an air dried sample varied greatly, the average, however, was about ten per cent. The following table shows the range of variation.

TABLE NO. 2.

ABSORPTION OF MOISTURE

| No. of Sample. | Per cent of Lime. | Pressure in Molding. | Absorption per cent |
|---|---|---|---|
| 1 | 48 | 10,000 | 11.9 |
| 2 | 48 | 9,000 | 12.6 |
| 3 | 48 | 5,000 | 12.7 |
| 8 | 40 | 5,000 | 15.7 |
| 9 | 40 | 10,000 | 7.8 |
| 10 | 40 | 15,000 | 20 1 |
| 11 | 50 | 5,000 | 5.5 |
| 12 | 50 | 10,000 | 6.7 |
| 13 | 50 | 15,000 | 8.5 |
| 14 | 60 | 5,000 | 14.7 |
| 15 | 60 | 10,000 | 16.0 |
| 16 | 60 | 10,000 | 13.4 |

The shrinkage due to the hardening process was so slight that no definite data was taken. Suffice it to say that no change in volume was perceptible in the samples made.

*Chemical Analyses*—In the free lime content, the variation was also considerable. In most cases about five per cent of the lime used remained in the free state. But, contrary to our expectations we found that the percentage of free lime increased with increasing pressures in the mold. In every instance, save one, was this found to be the case

that one exception is probably satisfactorily explained on other ınds. The following table gives the relative amounts of free lime aining in the samples.

TABLE No. 3.

CHEMICAL ANALYSIS.

| No. of Sample. | Per cent Lime Used as CaO. | Free lime as Ca O in the product. |
|---|---|---|
| 1 | 48 | 9.45 |
| 3 | 48 | 6.30 |
| 8 | 40 | 1.5 |
| 9 | 40 | 2.95 |
| 10 | 40 | 2.70 |
| 11 | 50 | 3.25 |
| 12 | 50 | 4.75 |
| 13 | 50 | 4.80 |
| 14 | 60 | 3.45 |
| 15 | 60 | 3.85 |
| 16 | 60 | 5.00 |

he combined lime was determined by difference between the free total lime, and gave little difficulty although the error due to com- d carbon dioxide was thrown upon this determination. The free combined silica were determined by a process having for its basis solubility of the latter in dilute solutions of hydrochloric acid and um carbonate. This determination, simple in theory, is not so sim- in practice and gives much difficulty. The evidence thus far ob- ed points to a definite formula for the product. Results are not ever as yet final.

ne block was heated in a muffle furnace to a red heat, for half an . It was ruptured by large cracks and later fell into several pieces. separate pieces were hard, but filled with many small cracks. It ident that this was caused by loss of water of hydration. The s remained firm until the dehydrated lime took up water again ı they fell to pieces.

ore work will be done on mixtures of silica with lime and the us other substances.

# CONTRIBUTIONS TO THE STUDY OF COAL.

## Contents.

## Introduction.

(By H. Foster Bain.)

From the first the study of coal and the coal fields has been considered one of the most important functions of the State Geological Survey. At present it absorbs a very considerable portion of the total funds available. In the following pages are presented in preliminary form some of the results so far attained. That so much can here be presented is only possible through the coöperation of a considerable number of individuals and organizations as already noted. While the results are in large measure preliminary and subject to correction it is believed they have sufficient validity to warrant their publication at this time.

The first paper, by Professor Parr and Mr. Wheeler, has grown out of the attempt to find a constant which may be used in comparing such coals as occur in Illinois. It is believed that the results here given are a step towards such a constant and present an advance upon earlier views despite certain irregularities. The results are available for present use only within the limits of error indicated and no attempt should be made to use them where greater refinement is desired.

That coals spontaneously alter while in laboratory storage was one of the unexpected discoveries of our work in 1906 and in the second paper Professor Parr and Mr. Wheeler give the results of studies directed to discover the amount and rate of this change. It is shown to be sufficient to require consideration in all comparisons of coals analyzed at different times so that hereafter it is important to know the length of time intervening between the taking of the sample and the making of the analysis.

The paper by Messrs. Parr and Francis includes further observations on certain very interesting changes in coal composition brought about artificially and at relatively low temperatures. Their studies are still under way and seem likely to yield results of large economic importance.

The importance of finding suitable methods of storing our coals is ample justification for any attempt to solve the problems involved in coal weathering. The results here published were obtained by Messrs. Parr and Hamilton in a preliminary study made in 1906-7 on small samples, mainly with a view to determine the methods to be used in a more complete investigation. The latter is now under way and reports will be later issued. In the meantime the preliminary work yielded certain results of qualitative value with it seems worth while to publish here. As indicated in the text the curves shown should be read with

view to the determination of the direction of change in the coal rather ian the absolute amount of the change though they indicate certain f the limits, at least, of the latter.

Mr. Bement's paper on ash in coal is a timely contribution to a subect of wide importance. It is based upon results obtained by him in rivate practice and is published here by his courtesy.

The papers by Messrs. DeWolf and Udden present some of the reults of the detailed field surveys now under way. These stratigahic studies are being directed toward the obtaining of a complete tructural section across the southern portion of the State and of full nowledge of the structure and stratigraphy of certain other importnt areas. It is believed that the detailed study of these areas is amply varranted by their large economic importance and the abundance of ie data available. General stratigraphic studies of the coal fields as whole were carried on during the year by Messrs. DeWolf, David Vhite and others as detailed elsewhere in this report. This work is eing done in coöperation with the U. S. Geological Survey.

# AN INITIAL COAL SUBSTANCE HAVING A CONSTANT THERMAL VALUE.

(By S. W. Parr and W. F. Wheeler.)

From a number of sources there has been developed the idea that in any given type of coal, or perhaps less broadly, in any given deposit of coal, there exists an initial substance with certain uniformities as to composition and calorific value, which might make it serve as a basis for very important considerations, both of a technical and a scientific nature. To be of any special advantage, such a unit substance should be constant within rather narrow limits, and it is the purpose of this paper to present the facts as developed up to the present time and to derive, if possible, a notion as to the probable outcome of this idea.

It is realized at once that a very great value will attach to the fact if it may be proved that in any given case there is a unit coal with fairly definite heat value. For a given region or mine, for example, where such values were established, it would be possible to calculate heat units upon the simple determination of the extraneous material such as water, ash and sulphur. Or it would be possible to correct heat determinations or confine them within the limits of variation recognized as inherent in the unit substance. Especially, also, would such a unit substance serve as a basis for studying losses by oxidation or other processes of deterioration.

Probably the first recognition of such a unit if found in the discussion by Lord and Hass.* From numerous analyses of Pennsylvania and Ohio coals, they draw a comparison between the heat values as derived by Dulong's formula, the Mauler Calorimeter and those calculated from a unit value which they designate as "H" and describe as being the value for the ash, water and sulphur free substances. They find the sulphur to be a disturbing element and correct for it in a partial manner only. However, they are justified in the conclusion that

> "On comparing the results, seam by seam, it would appear that the actual coal of a given seam, at least over considerable areas, may be regarded as essentially of uniform heating value."

The expression "actual coal," presumably refers to this same initial or unit substance, free from extraneous matter such as ash, moisture and sulphur. The idea is evidently intended in the further quotation below, though the same qualification as to '"actual coal," is not used thus:

*Trans. of the Amer. Inst. Min. Eng., vol. 27; p. 259.

"The results of our tests seem to indicate the interesting conclusion that the character of a coal seam, as far as its fuel value is concerned, is a nearly constant quality over considerable areas. The determination of the value for seams would be of great use, as the rapid proximate analysis, or for that matter, merely the determination of ash and moisture in low sulphur coals, would be sufficient to grade coals of the same vein. Of course, it is dangerous to argue from so few examples but the proposition seems reasonable. At least, we hope that further work may confirm these conclusions."

Kent, in discussing this paper in the same volume, (page 946), says:

"The conclusions of the authors that the "actual coal," (moisture and ash excluded), of a given seam over considerable areas, may be regarded as of uniform heating value, is one of great practical importance. I have held the same position tentatively for a long time."

Another development of this general idea is found in numerous articles by Mr. Bement of Chicago. For example*, referring to the advantage of having certain units of reference, he says:

The possibility of the more extended use of constants is presented, and the author urges the feasibility of considering the pure coal compositions as constants for a coal seam, or particular locality of such seams. This possibility has been suggested, principally by the fact that the heating power of the pure coal from a general locality does not vary over greater limits than that of the calorimetric method, and he has been able to employ it as a constant in calculating the heating power of dry and moist coal, having determined only moisture and ash, and obtained results that check with calorimetric determinations made on the same samples. The author, however, does not claim originality in this observation but does insist that the use of such constants is of advantage........This view concedes that coal from a certain locality or seam does not vary in quality, but that the variation is due to the presence of ash and moisture, which are impurities associated with coal."

In the subsequent paper† he argues for the same constance of values when referred to the pure coal basis. These considerations have, no doubt, led Mr. Bement to adopt the term "pure coal" as expressive of this idea of constancy in the "ash and water free" subtance, in addition to the fact of its being a more compact and convenient term to use.

However, in both these propositions, it is evident that several variables fail of recognition to the extent that they are not included in the extraneous matter of the vein substance, and since they certainly do not belong to the "actual coal," the question arises as to whether or not we yet have a fair basis of reference for drawing conclusions as to the constancy of our initial coal. For example, in coals of the western or bituminous type, the sulphur may vary from 1 to 5, or even 6 per cent. Indeed, variations of 2 or 3 per cent may be possible within the product from the same seam, especially where washing of the coal is in vogue. Now, if this variable is thrown into the "actual coal" content, it, by so much, prohibits any constancy of heat values being credited to that hypothetical constituent. The same thing is true of water of hydration. If the shale constant of the ash has, for example, 8 per cent of such water of hydration and the same is not counted with the ash, but as part of the "actual coal," here again is a disturbing element quite as troublesome as the sulphur. Similar variables would

*Jour. Amer. Chem. Soc., vol. 28, p. 636.
†Jour. Western Soc. of Eng., vol. 11, p. 757.

accompany the presence of gypsum or calcium carbonate. This matter of variables is discussed in a recent paper by Mr. W. F. Wheeler.* For the purpose of illustrating by specific cases the effect of including these variables in the combustible matter, instead of in the ash, and so allowing them to pass as part of the "actual coal," the following experimental data are presented: In the table below, samples of coal have been separated into coals of high and low ash content by floating in a solution of zinc sulphate of 1.35 specific gravity, whereby the purer coal with low ash and less iron pyrites has been separated, by floating, from the heavier particles with higher ash and more sulphur, the latter sinking to the bottom. Now, upon the hypothesis that the "actual coal" in these two divisions of the same sample should have the same heat value, the subjoined table is arranged to show what widely divergent values may be indicated by reason of different methods of arriving at the actual coal constituent. For example, if we credit to this material everything excepting the ash and moisture, we will have unit values as shown under column (a) of the table. If we narrow the actual coal down to everything but the ash, moisture and sulphur, counting all of the latter as in the pyritic form, we shall have values as shown under column (b) of the table. But not only is sulphur variable as to its method of combination whether organic or pyritic, but an additional variable should be made note of, viz., the water of hydration of the ash. These variables are accounted for in columns marked (c), (d), and (e) of the table. A general study of the shales of this region would seem to indicate an average hydration of 8 per cent for such material. Consequently, in column (c) the x stands for 8 per cent of the total ash as determined. In column (d) the x" stands for 8 per cent of hydration of the shale or clayey constitutent only, not including the iron pyrites as being subject to this addition of 8 per cent, the iron pyrites being calculated on the assumption that all of the sulphur is so combined. In column (e) the same procedure is followed with the exception that the iron pyrites is calculated on the basis of the iron present, thus making the constituents, exclusive of the actual coal, to consist of moisture, clayey-ash, hydration of the same, iron and sulphur as iron pyrites and organic sulphur.

It is evident from an examination of these several columns that the heat values for the "actual coal" draw nearer together as we proceed in this refinement of the material which we have designated provisionally as "actual" or "unit coal." This table, therefore, so far as it goes, seems to point to the fact of a unit value and also to a fairly accurate means of arriving at its factor. The calculations necessary under column (e) call for one additional constituent, not ordinarily furnished by chemical analysis, i. e., the percentage of iron present. This involves no difficulties and would not be necessary if it were not for the fact that considerable areas of coal exist where the iron content and consequently the sulphur as pyrites is relatively small, while in other regions the sulphur is very largely pyritic. The feature is characteristic of samples 2 and 4 of the table. The formulæ for these various calculations are sufficiently explained in the notes (a), (b), (c), (d) and (e) following the table.

*Trans. Amer. Inst. Min. Eng. vol. 38, p. 620.

TABLE NO. I—*Comparative Value of "Actual Coal."*

| Number | Description of Sample. | | Oven Dry Coal. | | | | Heat Value of "Actual Coal" as Calculated by Different Methods. (See notes below.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ash | Sulphur | Iron | B. t. u. | (*a*) B. t. u. Ash and Water free | (*b*) B. t. u. Ash, Water and Sulphur free | (*c*) Ash, water Sulphur and X′ Free | (*d*) Ash, Water Sulphur and X″ Free | (*e*) Ash, Water Sulphur and X‴ Free |
| 1 | Sangamon Co. Ill., lump coal. | Untreated | 11.66 | 5.99 | 3.38 | 12356 | 13987 | 14319 | 14478 | 14375 | 14552 |
| 2 | | Floated Sp. gr. less than 1.35 | 6.12 | 3.20 | .65 | 13300 | 14164 +177 | 14335 +16 | 14412 —66 | 14362 —13 | 14547 —5 |
| 3 | Sangamon Co., Ill., screenings. | Untreated | 18.21 | 4.25 | 2.37 | 11478 | 14031 | 14285 | 14555 | 14475 | 14613 |
| 4 | | Floated, Sp. gr. less ehan 1.35 | 8.13 | 2.95 | .70 | 13043 | 14192 +161 | 14356 +71 | 14460 —95 | 14413 —62 | 14579 —34 |
| 5 | Williamson Co. Ill. washed nut coal. | Untreated | 12.83 | 1.85 | 1.09 | 12523 | 14361 | 14471 | 14648 | 14615 | 14664 |
| 6 | | Floated, Sp. gr. less than 1.35 | 4.01 | 1.39 | .54 | 13929 | 14509 +148 | 14585 +114 | 14634 —14 | 14613 —2 | 14677 +13 |
| 7 | LaSalle Co. Ill.. washed screenings. | Untreated | 10.05 | 3.43 | 2.32 | 12885 | 14316 | 14517 | 14648 | 14592 | 14654 |
| 8 | | Floated, Sp. gr. less than 1.35 | 3.94 | 2.33 | 1.29 | 13922 | 14487 +171 | 14619 +102 | 14665 +17 | 14630 +38 | 14693 +39 |
| 9 | Vigo Co. Ind., nut coal. | Untreated | 16.84 | 7.62 | 5.17 | 11790 | 14170 | 14653 | 14902 | 14755 | 14911 |
| 10 | | Floated, Sp. gr. less than 1.35 | 4.27 | 3.08 | 1.06 | 13870 | 14478 +308 | 14653 +0 | 14705 —197 | 14657 —98 | 14797 —113 |
| 11 | Sullivan Co. Ind., lump coal. | Untreated | 6.11 | 3.37 | 2.24 | 13664 | 14551 | 14738 | 14819 | 14764 | 14825 |
| 12 | | Floated, Sp. gr. less than 1.35 | 2.53 | 1.29 | .36 | 14259 | 14624 +73 | 14709 —29 | 14729 —90 | 14709 —55 | 14773 —52 |

## *Table No. I*—Concluded.

| Number | Description of Sample. | | Oven Dry Coal. Ash | Oven Dry Coal. Sulphur | Oven Dry Coal. Iron | Oven Dry Coal. B. t. u. | Heat Value of "Actual Coal" as Calculated by Different Methods. (See notes below.) (a) B. t. u. Ash and Water Free | (b) B. t. u. Ash, Water and Sulphur Free | (c) Ash, Water Sulphur and X′ Free | (d) Ash, Water, Sulphur and X″ Free | (e) Ash, Water, Sulphur ann P‴ Free |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Franklin Co. Ill., face sample. | Sp. gr. greater than 1.35 | 18.00 | .57 | Not determi'd | 11639 | 14194 | 14227 | 14485 | 14474 | ........ |
| 14 | | Sp. gr. less than 1.35 | 4.64 | .54 | ..do.... | 13765 | 14435 +241 | 14562 −235 | 14518 +33 | 14512 +38 | ........ |
| 15 | Franklin Co., Ill., face sample. | Sp. gr. greater than 1.35 | 14.43 | 1.45 | ..do.... | 12142 | 14190 | 14271 | 14469 | 14445 | ........ |
| 16 | | Sp. gr. less than 1.35 | 3.83 | .71 | ..do.... | 13918 | 14472 +282 | 14510 +239 | 14556 +87 | 14545 +100 | ........ |
| 17 | Perry Co. Ill., face sample. | Sp. gr. greater than 1.35 | 22.17 | 1.55 | ..do.... | 10922 | 14033 | 14016 | 14435 | 14413 | ........ |
| 18 | | Sp. gr. less than 1.35 | 4.22 | .86 | ..do.... | 13763 | 14369 +336 | 14414 +318 | 14466 +31 | 14452 +39 | ........ |
| 19 | Perry Co. Ill., face sample. | Sp. gr. greater than 1.35 | 9.52 | .65 | ..do.... | 12947 | 14309 | 14343 | 14468 | 14458 | ........ |
| 20 | | Sp. gr. less than 1.35 | 2,66 | .74 | ..do.... | 13985 | 14367 +58 | 14404 +61 | 14436 −32 | 14426 −32 | ........ |
| 21 | Williamson Co., Ill., face sample. | Sp. gr. greater than 1.35 | 17.75 | 1.15 | ..do.... | 11766 | 14306 | 14374 | 14628 | 14608 | ........ |
| 22 | | Sp. gr. less than 1.35 | 4.08 | .99 | ..do.... | 13942 | 14535 +229 | 14587 +213 | 14639 −11 | 14623 −15 | ........ |
| 23 | Williamson Co., Ill., face sample. | Sp. gr. greater than 1.35 | 18.28 | 1.37 | ..do.... | 11731 | 14355 | 14434 | 14705 | 14682 | ........ |
| 24 | | Sp. gr. less than 1.35 | 4.34 | 1.07 | ..do.... | 13970 | 14604 +249 | 14657 +223 | 14715 +10 | 14699 +17 | ........ |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | Franklin Co., Ill., face sample. | Sp. gr. greater than 1.35 | 10.89 | 1115 | ..do... | 12917 | 14495 | 14558 | 14705 | 14687 | ........... |
| 26 | | Sp. gr. less than 1.35 | 3.40 | .98 | ..do... | 14092 | 14588<br>+93 | 14641<br>+83 | 14680<br>—25 | 14665<br>—22 | ........... |
| 27 | Williamson Co., Ill., face sample. | Sp. gr: greater than 1.35 | 13.41 | 2.27 | ..do... | 12530 | 14458 | 14602 | 14790 | 14751 | ........... |
| 28 | | Sp. gr. less than 1.35 | 3.23 | 1.31 | ..do... | 14175 | 14649<br>+191 | 14718<br>+116 | 14758<br>—32 | 14738<br>—13 | ........... |

NOTE. The methods of calculating the values for the columns unde (a), (b), (c), (d) and (e) are explained in the following notes:

(a) $$\frac{\text{B. t. u. as determined}}{1.00-(\text{Moisture}+\text{Ash})}$$

(b) $$\frac{\text{B. t. u. as determined} - 4050\ \text{S}}{1.00 - (\text{Moisture} + \text{Ash} + \frac{5}{8}\ \text{S.})}$$

(c) $$\frac{\text{B. t. u. as determined} - 4050\ \text{S}}{1.00 - (\text{Moisture} + \text{Ash} + \frac{5}{8}\ \text{S} + 0.08\ (\text{Ash as determined.}))}$$

In this formula the expression 0.08 (ash as determined) is repre sented in the table by x'.

(d) $$\frac{\text{B. t. u. as determined} - 4050\ \text{S}}{1.00 - [\text{Moisture} + \text{Ash} + \frac{5}{8}\ \text{S} + 0.08\ (\text{Ash} - \frac{10}{8}\ \text{S.})]}$$

In the formula for the calculation under (d) the expressio (Ash-10/8 S) is intended to account for the ash with removal of the iro oxide. This is based on the assumption that all the sulphur of the coa is in the pyritic form and that the iron oxide resulting from burnin is equivalent to 10/8 of the total sulphur. Hence the expressio 0.08 (Ash-10/8 S of the formula is represented in the table by x".

(e) $$\frac{\text{B. t. u. as determined} - 4050\ \text{S}}{1.00 - [\text{Moisture} + (\text{Ash} - \frac{10}{7}\ \text{Fe}) + 0.08\ (\text{Ash} - \frac{10}{7}\ \text{Fe}) + \frac{15}{7}\ \text{Fe} + (\text{S} - \frac{8}{7}\ \text{Fe.})]}$$

In this formula the iron weighed in the ash as $Fe_2O_3$ is represente by the expression 10/7 Fe. The expression 15/7 Fe represents the iro present calculated to iron pyrites. The expression 8/7 Fe represent the sulphur necessary to unite with the iron to form $FeS_2$. Hence th expression 0.08 (Ash-10/7 Fe) of the formula is represented in th table by x‴, with the added provision that the sulphur in the pyriti form is limited to the actual iron present.

It is not intended to argue from the preceding table that a fina method for deriving a unit coal has been evolved. More data is neede to test out the matter and indeed other methods may be devised, givin more direct and positive access to the "actual coal" values. Wher so many variables enter into the proposition, such as the age of th sample, the effect of weathering or oxidation conditions, the composi tion of the ash, the organic or pyritic nature of the sulphur, etc., a immature conclusion is to be avoided. The purpose of this paper i to make record of the evidence thus far available towards the estab lishment of such fundamental unit values and, as already indicated the results in the table constitute a strong argument in favor of th proposition.

The evidence as there given depends chiefly upon the elimination o impurities and the isolation of the "actual coal" in a few samples hav ing sufficient analytical data to permit of such procedure. There i still very interesting data at hand if we take all of the recent record of the laboratory upon coals from widely distributed areas, and calcu late their heat values to such a unit of "actual coal" as the analytica results will permit.

These values, therefore, have been calculated to an ash, water and ulphur free basis as in column (b) of the preceding table.

The results are grouped in tables corresponding to the commonly lesignated seam numbers, but correlation of beds of the same number is not implied. The grouping in each table so far as such is indicated, is by proximity of mines in a given locality.

## Table No. 2.

*Illinois "Number 5" Coal from Central Part of the State.*

| | Oven Dry Coal. | | | B. t. u. of Ash, Water and Sulphur Free Coal. |
|---|---|---|---|---|
| | Ash. | Sulphur. | B. t. u. | |
| Sangamon county | 10.76 | 4.78 | 12749 | 14567 |
| Sangamon county | 13.81 | 3.56 | 12426 | 14626 |
| Sangamon county | 13.64 | 4.61 | 12304 | 14532 |
| *Sangamon county | 12.75 | 4.11 | 12369 | 14408 |
| *Sangamon county | 12.47 | 4.28 | 12416 | 14429 |

* From the same mine.

## Table No. 3.

*Illinois "Number 5" Coal from Southern Part of the State.*

| | Oven Dry Coal. | | | B. t. u. of Ash, Water and Sulphur Free Coal. |
|---|---|---|---|---|
| | Ash. | Sulphur. | B. t. u. | |
| Williamson county | 10.68 | 3.86 | 13073 | 14862 |
| *Gallatin county | 10.85 | 3.72 | 13235 | 15188 |
| *Saline county | 12.68 | 6.12 | 12879 | 15131 |
| Saline county | 10.54 | 3.12 | 13212 | 14952 |
| Saline county | 11.49 | 4.16 | 12931 | 14856 |
| Saline county | 9.21 | 2.35 | 13367 | 14857 |
| Saline county | 8.99 | 3.52 | 13415 | 14945 |
| Saline county | 7.62 | 2.30 | 13700 | 14962 |
| Saline county | 9.04 | 2.47 | 13450 | 14931 |
| Saline county | 11.58 | 3.26 | 12942 | 14830 |
| Saline county | 9.89 | 2.37 | 13289 | 14895 |

* Samples from mines about 3 or 4 miles apart and at a greater distance from the other line county mines.

TABLE NO. 4.

*Illinois "Number 7" Coal.*

| | Oven Dry Coal. | | | B. t. u. of Ash, Water and Sulphur Free Coal. |
|---|---|---|---|---|
| | Ash. | Sulphur. | B. t. u. | |
| 1*Franklin county | 10.11 | .60 | 12985 | 14480 |
| 2*Franklin county | 7.53 | .91 | 13312 | 14445 |
| 3 Perry county | 12.11 | .91 | 12603 | 14386 |
| 4 Franklin county | 8.08 | 1.19 | 13400 | 14644 |
| 5 Williamson county | 10.13 | 1.12 | 13078 | 14615 |
| 6 Williamson county | 7.66 | 1.89 | 13475 | 14781 |
| 7 Williamson county | 8.48 | 1.03 | 13323 | 14615 |
| 8 Williamson county | 10.65 | 2.50 | 13016 | 14710 |
| 9 Saline county | 13.79 | 3.73 | 12505 | 14728 |
| 10 Saline county | 11.50 | 4.46 | 12744 | 14658 |

* From same mine.

TABLE NO. 5.

*Illinois "Number 6" Coal.*

| | Oven Dry Coal. | | | B. t. u. of Ash, Water and Sulphur Free Coal. |
|---|---|---|---|---|
| | Ash. | Sulphur. | B. t. u. | |
| 1 Sangamon county | 12.23 | 5.03 | 12372 | 14378 |
| 2a Sangamon county | 11.04 | 4.55 | 12640 | 14463 |
| 3a Macoupin county | 11.90 | 4.33 | 12440 | 14368 |
| 4 St. Clair county | 11.23 | 4.37 | 12723 | 14582 |
| 5 Clinton county | 13.98 | 5.29 | 12232 | 14505 |
| 6 Clinton county | 10.47 | 4.80 | 12815 | 14585 |
| 7b Madison county | 11.72 | 5.17 | 12499 | 14450 |
| 8b Madison county | 10.59 | 4.12 | 12681 | 14410 |
| 9 Madison county | 13.65 | 2.81 | 12114 | 14186 |
| 10 Christian county | 13.50 | 4.71 | 12203 | 14374 |
| 11c Clinton county | 10.78 | 3.96 | 12659 | 14408 |
| 12c Clinton county | 13.59 | 4.52 | 12246 | 14432 |
| 13d Clinton county | 11.15 | 1.65 | 12569 | 14237 |
| 14d Clinton county | 16.56 | 2.99 | 11639 | 14174 |
| 15e Macoupin county | 10.86 | 5.38 | 12469 | 14282 |
| 16e Macoupin county | 11.40 | 4.41 | 12360 | 14196 |
| 17 Macoupin county | 12.87 | 5.48 | 12303 | 14301 |
| 18f St. Clair county | 12.23 | 4.37 | 12604 | 14640 |
| 19fg St. Clair county | 9.69 | 3.33 | 12982 | 14564 |
| 20g Madison county | 11.22 | 4.85 | 12762 | 14659 |
| 21h St. Clair county | 11.07 | 4.70 | 12706 | 14555 |
| 22h St. Clair county | 12.00 | 4.72 | 12587 | 14577 |
| 23h St. Clair county | 12.73 | 4.02 | 12428 | 14472 |
| 24i St. Clair county | 12.94 | 4.90 | 12701 | 14885 |
| 25i St. Clair county | 12.47 | 4.19 | 12587 | 14611 |
| 26i St. Clair county | 15.80 | 4.76 | 12202 | 14785 |
| 27j St. Clair county | 13.43 | 3.23 | 12290 | 14387 |
| 28j St. Clair county | 12.53 | 2.13 | 12486 | 14394 |

Pairs of samples marked a, b, h and j, are from mines about two miles apart.
Pairs of samples marked c and d, are from mines about one mile apart.
Pairs of samples marked g and i, are from mines about three or four miles apart.
Pairs of samples marked e and f, are from the same mine.

No serious attempt has been made in the above tables to define areas by coal of a given value. At some future time and upon the accumulation of more data it may be possible to group areas in such a manner as to show very concordant values for a given district or locality, but it would be premature to attempt such divisions at the present time.

Attention should be called again to the variables of age and weathering of samples, the effect of which, as yet, cannot be definitely formulated. In the foregoing tables the samples are all taken from the face

of the coal, forwarded in tins by express in the usual manner, and the calorimetric values obtained in from 5 to 14 days from the time of collecting at the face of the seam.

A number of results have also been obtained in this laboratory upon commercial samples which have been subjected to the ordinary conditions of time and exposure for coal shipped from mine to consumer in car lots. The average time involved for the samples from Illinois would be approximately three weeks. It is probable that in case of the samples from Colorado, a longer time elapsed between mining and the date of making the calorimetric determinations. These values from three widely separated regions are remarkably concordant with themselves and show in each case heat values which are very characteristic of the several types of coal.

TABLE NO. 6.

| Coal from Christian county Illinois. | B. t. u. of Ash, Water and Sulphur Free Coal. | B. t. u. Variation from Average. | Per cent of Variation from Average. |
|---|---|---|---|
| | 14299 | — 55 | .38 |
| | 14415 | + 61 | .43 |
| | 14402 | + 48 | .33 |
| | 14352 | — 2 | .01 |
| | 14337 | — 17 | .12 |
| | 14405 | + 51 | .36 |
| | 14448 | + 94 | .66 |
| | 14377 | + 23 | .16 |
| | 14419 | + 65 | .45 |
| | 14415 | + 61 | .43 |
| | 14412 | + 58 | .40 |
| | 14478 | +124 | .85 |
| | 14273 | — 81 | .56 |
| | 14405 | + 51 | .36 |
| | 14370 | + 16 | .11 |
| | 14363 | + 9 | .06 |
| | 14290 | — 64 | .45 |
| | 14318 | — 36 | .25 |
| | 14502 | +148 | 1.03 |
| | 14506 | +152 | 1.06 |
| | 14406 | + 52 | .36 |
| | 14517 | +163 | 1.14 |
| | 14443 | + 89 | .62 |
| | 14403 | + 49 | .34 |
| Deliveries covering a period of 6 months from a single mine. | 14360 | + 6 | .04 |
| | 14420 | + 66 | .46 |
| | 14460 | +106 | .74 |
| | 14311 | — 43 | .30 |
| | 14416 | + 62 | .43 |
| | 14400 | + 46 | .32 |
| | 14310 | — 44 | .31 |
| | 14292 | — 62 | .43 |
| | 14276 | — 78 | .54 |
| | 14277 | — 77 | .54 |
| | 14304 | — 50 | .35 |
| | 14376 | + 22 | .15 |
| | 14380 | + 26 | .18 |
| | 13302 | + 48 | .33 |
| | 14288 | — 66 | .46 |
| | 14349 | — 5 | .03 |
| | 14350 | — 4 | .03 |
| | 14255 | — 99 | .69 |
| | 14378 | + 24 | .17 |
| | 14311 | — 43 | .30 |
| | 14260 | — 94 | .66 |
| | 14123 | —231 | 1.61 |
| | 14198 | —156 | 1.09 |
| | 14168 | —186 | 1.30 |
| | 14213 | —141 | .98 |
| | 14324 | — 30 | .21 |
| | 14285 | — 69 | .48 |
| | 14353 | — 1 | .01 |
| Average.................. | 14354 | ± 66 | ± .46% |

TABLE No. 7.

| Coal from Boulder county, Colorado. | B. t. u. of Ash, Water and Sulphur Free Coal. | B. t. u. Variation from Average. | Per cent of Variation from Average. |
|---|---|---|---|
| Deliveries from two neighboring mines. | 12871 | —50 | .39 |
| | 12979 | +58 | .45 |
| | 12960 | +39 | .30 |
| | 12891 | —30 | .23 |
| | 13030 | +109 | .84 |
| | 13154 | +233 | 1.82 |
| | 13099 | +178 | 1.38 |
| | 12949 | +28 | .22 |
| | 13063 | +142 | 1.10 |
| | 13007 | +86 | .66 |
| | 12970 | +49 | .38 |
| | 13084 | +163 | 1.26 |
| | 12692 | —229 | 1.77 |
| | 12780 | —141 | 1.09 |
| | 12782 | —139 | 1.07 |
| | 12843 | —78 | .60 |
| | 12850 | —71 | .55 |
| | 12846 | —75 | .58 |
| | 12901 | —20 | .15 |
| | 12873 | —48 | .37 |
| | 12876 | —45 | .35 |
| | 12905 | —16 | .12 |
| | 12781 | —140 | 1.08 |
| | 12907 | —14 | .11 |
| Average | 12921 | ± 91 B.T.U. | ±.70% |

| Coal from Las Animas county, Colo. | B. t. u. of Ash, Water and Sulphur Free Coal. | B. t. u. Variation from Average. | Per cent of Variation from Average. |
|---|---|---|---|
| Deliveries from a single mine. | 15174 | +47 | +.31 |
| | 15189 | +62 | +.41 |
| | 15163 | +35 | +.23 |
| | 15184 | +57 | +.38 |
| | 15312 | +185 | +1.22 |
| | 15215 | +88 | +.58 |
| | 15162 | +35 | +.23 |
| | 15097 | —30 | —.20 |
| | 15241 | +114 | +.75 |
| | 15038 | —89 | —.59 |
| | 14949 | —178 | —1.18 |
| | 15000 | —127 | —.84 |
| | 15048 | —79 | —.52 |
| | 15000 | —127 | —.84 |
| Average | 15127 | ± 90 B.T.U. | ± .59% |

Concerning these commercial samples, it may be observed that a rather remarkable uniformity exists. This may be due to the restricted area from which the several samples came, or it may be due also to the fact that under commercial conditions of shipment as to age, etc., there is a tendency to equalize differences that are rather accentuated than otherwise in vein samples which are freshly taken and analyzed at the earliest possible date.

One other series is pertinent, therefore, in this connection. In table No-8 are given results on three samples wherein the sections of the

seam were kept distinct with reference to the "top," "middle" and "bottom" of the seam. These results are valuable because they show at a glance the necessity of care in taking face samples, to see that the cut is made equally and from the entire working face of the seam. It is evident also that lump or hand samples which are frequently taken for analysis are not only of little value but may be positively misleading and the error is quite as likely to be of a minus as of a plus character.

Here again it may be observed that these stratigraphic variations may be to a very large extent equalized, as above noted, by the ordinary commercial processes of handling the output in large masses.

TABLE NO. 8.

*Variations in the Calorific Value of the "Actual Coal" for Different Vertical Sections of the Seam.*

| No. | Description of Sample. | Oven Dry Coal. Ash. | Sulphur. | B. t. u. | B. t. u. of Ash, Water and Sulphur Free Coal. |
|---|---|---|---|---|---|
| | Collinsville, Illinois. | | | | |
| 1 | Top, 23 inches | 6.14 | 4.44 | 13505 | 14628 |
| 2 | Middle, 48 inches | 12.02 | 3.84 | 12618 | 14557 |
| 3 | Bottom, 22 inches | 14.86 | 7,52 | 12297 | 14908 |
| 4 | Entire face, 93 inches | 11.22 | 4,85 | 12762 | 14659 |
| | Belleville, Illinois. | | | | |
| 1 | Top, 4 inches | 6.75 | 3.35 | 13629 | 14801 |
| 2 | 1/4 inch, 2 inches from the top | 2.09 | 2.66 | 14255 | 14724 |
| 3 | Entire face, 76 1/2 inches | 12.47 | 4.19 | 12587 | 14611 |
| | DuQuoin, Illinois. | | | | |
| 1 | Top, 30 inches | 6.13 | .76 | 13573 | 14498 |
| 2 | Bottom, 69 inches | 14.71 | .98 | 12181 | 14338 |
| 3 | Entire face | 12.11 | .91 | 12603 | 14386 |

## CONCLUSIONS.

1. A unit substance provisionally designated as "actual coal" seems to exist for a given mine or for a more or less limited area.

2. The indications points to this unit substance as the ordinary coal free from moisture, clayey-ash, hydration of the clayey-ash, iron with the necessary sulphur to constitute pyrites, and the remaining sulphur undetermined as to its combinations.

3. The heat values for this unit coal show a sufficient uniformity to make it well worth while, especially in view of the possible advantages involved to follow with carefully correlated data, the evidences of constancy and the conditions and limits of variation, which characterize this material.

# Alterations of the Composition of Coal During Ordinary Laboratory Storage.

(By S. W. Parr and W. F. Wheeler.)

The State Geological Survey in coöperation with the Engineering Experiment Station of the University of Ilinois has developed a number of facts in the chemical study of coals of sufficient importance to receive consideration in any work upon this material whether of a technical or an investigational character. There is evidence that coal depreciates in fuel value from the time it is mined until it is used.

The deterioration is greatest at first and continues at a decreasing ate for an indefinite period of time. It is probably most active during he first two or three weeks after the coal is mined and even in the ase of small laboratory samples tightly sealed, it is still very appreciable in amount. A number of factors, such as temperature, exposure to the air, and size, affect the rate of alteration. If the coal is ntirely submerged in water, the loss is at a minimum, if the coal is exposed to the air in a warm place, the loss will reach the maximum.* This deterioration proceeds along two lines; one of a physical and the ther of a chemical nature.

The first of these changes seems to be a direct result of the removal f the coal from the seam. When the coal is taken from the ground, : is released from considerable pressure and is broken up so that a irge surface is exposed to the air. As soon as coal is thus exposed t begins to lose its absorbed combustible gases and to absorb non-ombustible gases from the air instead. The importance of this loss is, f course, dependent entirely upon the amount of gas originally in the oal. With some coals, the absorbed or occluded gases are considerble in amount and their loss may be of importance to the gas maker. Iowever, there are but few coals that contain as much as 1 per cent f such gas. A number of European and American gas manufacturers ave noticed a considerable difference in both the quantity and quality of the gas made from coal that had been stored for a few weeks.† Less gas and gas of a lower heating value was obtained from the tored coal than was made from the same kind of coal used soon after : was mined.

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*See "Weathering of Coal" in this Bulletin, p. 190-204.
†Dr. Habermann, J., Gasbel, vol. 49, p. 419.

Our first positive evidence of the loss of occluded gases was furnished by a number of laboratory samples. Some of the first samples that were collected by the Geological Survey in the summer of 1906 were kept in the laboratory for nearly a year before the chemical work was begun upon them. The samples in question were collected in the mines as face samples and were sent to the laboratory in sealed galvanized iron cans. When they arrived at the laboratory they were at once transferred to one-quart glass jars. Twenty-nine samples were placed in jars of the type shown herewith, known as the "lightning" or "Putnam" jar. Extended experience with this jar as a container for sodium peroxide, a chemical with unusual avidity for moisture from the atmosphere, has proved it to be possessed of a nearly perfect seal. The remaining twenty-one samples were placed in common Mason jars with metal caps and a very indifferent seal. After standing about ten months, the "Lightning" jars were opened and a slight pressure of gas was noted which suggested the testing of the same with a lighted match. In twenty-six of these jars the gas ignited with a strong blue flame, burning up from one-half inch to six inches above the top of the jar. Upon covering with the cap and testing again with a match, the gas from these jars would reignite for two or three successive times. Two of the jars had been previously opened without testing the gas, so it is not known whether they contained inflammable gases or not. In one of the jars tested, the gas was almost entirely nitrogen and it extinguished the lighted match. Not one of the twenty-one Mason jars with the metal cover contained any gas under pressure and no tendency to ignite was manifested. It should be noted that all of these jars were in diffused light, but not in the direct sunlight, and that only the "Lightning" jars possessed a perfect seal. The jars in question were all full of coal to within one inch or less of the top. By referring to figure 4, it will be seen that, with the exception of the

FIG 4. "Lightning" Containers for Coal Samples.

rubber gasket, the entire inclosure of the material is of glass. The gasket, however, is an exception to this, but it is held with a very positive pressure by reason of the lever device for clamping on the top. The conditions in the ordinary Mason jar are different in that a metal screw cap is employed and the completeness of the seal of the rubber gasket is questionable.

The above positive evidence of the release of combustible gas from the coal after it is broken out of the seam will account in part for the decrease in the heating value of the coal. If the exudation of combustible gases is accompanied by a corresponding absorption of non-combustible gases, oxygen, nitrogen and carbon dioxide, as Richter* and others seem to have proved, a considerable part of the apparent loss will be thus acounted for. That part of the indicated loss which is due, therefore, to the absorption of inert gases, does not represent an actual loss, but results from the increased weight of the coal.

The second process responsible for the loss in the calorific value of the coal is entirely chemical in nature and is probably the direct oxidation of the carbon, hydrogen and sulphur in the coal. This second process is not so active in small sealed samples as it is in the larger lots of coal exposed to the air, but even in laboratory samples it is active as long as oxygen is present, the rate of oxidation being dependent on the temperature, and increasing rapidity as the temperature increases. A large number of old samples have been examined in this laboratory and the majority of them showed only 1 or 2 per cent of oxygen in the atmosphere of the jar. These samples had all been exposed to the air and air dried, and had been opened more or less at the time they were being analyzed, thus permitting any inflammable gases to be lost; subsequently, however, they had stood unopened for various lengths of time, from six months to three years. Out of twelve one-quart "Lightning" jars, each a little less than one-fourth full of buck-wheat size coal, five contained as little oxygen as to extinguish a lighted match as soon as it was placed in the mouth of the jar.

The pyrite and marcasite in the stored samples also suffers from oxidation, especially if there is moisture present. Ferrous and ferric sulphate crystals have been noticed in a large number of samples, sometimes within a very few months after the samples came into the laboratory. The amount of ferric sulphate and sulphuric acid derived from the oxidized pyrite was determined in one sample that had been unopened for three years and from this the amount of oxygen that had been used up was calculated. It was found to be 1.99 grams or 1.39 liters of pure oxygen, equivalent to 7 liters of ordinary air. When it is remembered that the jar in which this sample was kept had a volume all told of only one pint, and that this space was occupied to the extent of at least three-quarters of the total with coal of buckwheat size, and when we further remember that these jars are possessed of an apparently absolute seal without opportunity for transferrence of oxygen from without, there is further evidence of the fact that occluded

*Dinglers Poly. Jour., vol. 190, p. 398; vol. 195, p. 452.

oxygen or air must have been present in sufficient amount to accomplish the work indicated by the transformation of the pyrites to ferric sulphate and sulphuric acid, or that there was some actual decomposition of the coal itself. The above evidence of the deterioration of laboratory samples of coal is further borne out by the calorimetric determinations on a number of samples. In an article by one of the writers* reference is made to the necessity of making calorific determinations where comparisons between different instruments are involved, at approximately the same date. To quote from that article—"A comparison of calorimeters should be made at approximately the same time. A series of calorific determinations made on finely ground samples on May 12, 1900 was found to give a reading 2.4 per cent less on July 12, 1900. It was found necessary to repeat practically all of the results showing a deterioration in the finely ground samples. This subject will receive further attention later."

In the comparison of the calorific values of the first series of Illinois coals, analyzed by the State Geological Survey, with similar calorific values obtained by the United States Geological Survey Fuel Testing Plant of St. Louis, a considerable discrepancy was noted. The samples in both cases were taken from the face of the seam and were handled in identically the same way except that there was a considerable difference in the length of time between the collection of the sample and its analysis. The same type of calorimeter was used, the one in this laboratory being of the Mahler-Atwater design. It was operated in a room where the temperature could be kept very nearly constant. After due consideration of the possibility of the variation in results being accounted for by the difference in operators and laboratories, it was thought probable that the differences noted were due principally to the greater lapse of time between the collection and analysis of the State Geological Survey's samples. The correctness of this conclusion seems to be justified by the results from a similar series of samples which were analyzed immediately after collection.

The following tables show the constancy in direction and amount of the change of calorific value due to lapse of time between the collection and analysis of the samples.

*A New Calorimeter, by S. W. Parr, Jour. Amer. Chem. Soc., Oct. 1900, p. 650.

TABLE NO. I.

*Comparison of U. S. G. S. with Illinois G. S. Values.*

| U. S. G. S. No. | Ill. G. S. Lab. No. | Locality. | B. t. u. per 1 lb. Ash, Water and Sulphur Free Coal. | Difference in B. t. u. | Per cent of difference in B. t. u. |
|---|---|---|---|---|---|
| Ill. 1 | ........ | O'Fallon | 14567 | ........ | ........ |
| | 95, 96, 97 | * | 14214‡ | -353 | -2.4% |
| Ill. 3 | ........ | Marion | 14561 | ........ | ........ |
| | 330 | * | 14335 | -226 | -1.6 |
| Ill. 9 | ........ | Staunton | 14615 | ........ | ........ |
| | 91, 92, 93, 94 | * | 13933‡ | -682 | -4.7 |
| Ill. 10 | ........ | West Frankfort | 14647 | ........ | ........ |
| | 364 | † | 17332 | -315 | -2.2 |
| Ill. 14 | ........ | Springfield | 14464 | ........ | ........ |
| | 81, 82 | * | 14020‡ | -444 | -3.1 |
| Ill. 15 | ........ | Centralia | 14587 | ........ | ........ |
| | 167, 168, 169 | † | 14257‡ | -330 | -2.3 |
| Ill. 16 | ........ | Herrin | 14558 | ........ | ........ |
| | 322, 325 | * | 14267‡ | -291 | -2.0 |
| Ill. 18 | ........ | LaSalle | 14722 | ........ | ........ |
| | 393 | † | 14440 | -282 | -1.9 |

*Samples not from mine, but from adjacent mines.
†Samples from the same mine.
‡Average of several samples from neighboring mines.

## TABLE No. 2.

*Comparison of Values for Fresh and Old Samples by Illinois Geological Survey.*

| Ill. G. S. Lab. No. | Locality. | B. t. u. per lb. Ash, Water and Sulphur Free Coal | Difference in B. t. u. | Per cent of difference in B. t. u. |
|---|---|---|---|---|
| 421 | DuQuoin | 14386 | | |
| 307, 308, 309 | * | 14009‡ | −377 | −2.6 |
| 459, 460, & 1088 | Herrin | 14647‡ | | |
| 223 & 325 | * | 14285‡ | −362 | −2.5 |
| 460 | Clifford | 14615 | | |
| 325 | † | 14213 | −402 | −2.7 |
| 462 | Marion | 14781 | | |
| 330 | † | 14335 | −446 | −3.0 |
| 540, 740, 741 | Springfield | 14468‡ | | |
| 81 & 82 | * | 14020‡ | −448 | −3.1 |
| 557 | Westville | 14550 | | |
| 332 | † | 14054 | −496 | −3.4 |
| 558 | Himrod | 14564 | | |
| 333 | † | 14087 | −477 | −3.3 |
| 1111 | Eldorado | 14857 | | |
| 317 | † | 14597 | −278 | −1.9 |
| 358 | * | 14662 | −195 | −1.3 |
| 1114 | Harrisburg | 14931 | | |
| 315 | † | 14622 | −309 | −2.1 |
| 1110 | Eldorado | 15131 | | |
| 359 | † | 14939 | −192 | −1.3 |
| 1112 | Maryville | 14450 | | |
| 418 | † | 14134 | −316 | −2.2 |
| 1121 | Norris City | 14658 | | |
| 316 | † | 14322 | −336 | −2.3 |

*Samples not from mine, but from adjacent mines.
†Samples from the same mine.
‡Average of several samples from neighboring mines.

TABLE No. 3.

*Comparison of New U. S. G. S. Samples with New Samples by the Ill. S. G. S.*

| U. S. G. S. Lab. No. | Ill. G. S. Lab. No. | Locality. | B. t. u. per lb., Ash, Water and Sulphur Free Coal. | Difference in B. t. u. | Per cent of difference in B. t u. |
|---|---|---|---|---|---|
| Ill. 3 | ............ | Marion | 14561 | ............ | ............ |
| | 462 | † | 14781 | +220 | +1.5 |
| Ill. 4 | ............ | Troy | 14439 | ............ | ............ |
| | 1118 | † | 14168 | —271 | —1.9 |
| Ill. 7 | ............ | Collinsville | 14373 | ............ | ............ |
| | 723, 714, 725 | * | ‡14621 | +248 | +1.7 |
| Ill. 9 | ............ | Staunton | 14615 | ............ | ............ |
| | 735, 736, 737 | * | ‡14260 | —355 | —2.4 |
| Ill. 14 | ............ | Springfield | 14464 | ............ | ............ |
| | 540, 740, 741 | * | ‡14468 | +4 | + .03 |
| Ill. 16 | ............ | Herrin | 14558 | ............ | ............ |
| | 459, 460, 1008 | * | ‡14647 | +89 | + .6 |
| Ill. 19 | ............ | Ziegler | 14601 | ............ | ............ |
| | 419, 420 | † | 14463 | —138 | — .9 |

*Samples not from mine, but from adjacent mines.
†Samples from the same mine.
‡Average of several samples from neighboring mines.

It will be noted that in Table No. 1, the Illinois Geological Survey samples all show a considerably lower calorific value for the ash, water and sulphur free coal than do the United States Geological Survey samples. In all of the analyses there given, the samples had been in the State laboratory for six months or more before being analyzed whereas the United States Geological Survey samples were analyzed soon after they were collected.

In Table No. 2, the same variation is shown except that in this case the samples were all analyzed in the same laboratory, thus overcoming any differences that could have been due to that source. The samples that stood for six months or more in the laboratory, show a loss of about 2 per cent in heating value.

Table No. 3 is given to show the agreement between the two laboratories when the samples were analyzed soon after the collection in each case. Even in this table there is a considerable variation but it will be noticed that it is not all in the same direction as was the case where a greater and uniform difference in the length of time between collection and analysis existed and also it is much less in amount. In the extreme cases, United States Geological Survey No. 7 and Illinois Geological Survey Nos. 723, 724 and 725, where our results were 1.7 per cent higher than the St. Louis results, it was found that the lapse of time was twenty days and twelve days respectively. In the case of Illinois No. 9, and Illinois Geological Survey Nos. 736 and 737, the lapse of time was six days and twenty days respectively and our re-

sults were 2.4 per cent lower than the St. Louis results. In this connection, it will be interesting to note that in table No. 2, the samples showing the smallest loss, i. e., samples Nos. 358 and 359, each with 1.3 per cent loss, were kept in the laboratory only about three or four months instead of six months or more as were all of the other samples. Definite information is not at hand as to the length of time between the collection and analysis of any of the other United States Geological Survey samples, but, in the case of the two just mentioned, it will be seen that coal that stood longest in each case had the lower B. t. u., irrespective of the laboratory which made the analysis.

In the comparisons between samples where an average value is given the average is always very close to the value for each of the individual samples so that the direction and magnitude of the variation would not be materially affected if the comparison were made with the individual samples.

It is interesting, also, to bring together the averages of the results in the three preceding tables for further comparisons, so as to note the extreme uniformity of the variation that exists between old and new samples, and also to note the agreement between the two laboratories when fresh samples are used by both.

## TABLE NO. 4.

*Averages from Tables Nos, 1, 2 and 3.*

Table No. 1.

| | |
|---|---|
| 17 Illinois Geological Survey samples compared with 8 United States Geological Survey samples. Illinois Geological Survey samples analyzed 6 months to 1 year after collection. U. S. G. S. analyses made soon after collection. | Older samples. Average 365 B. t. u. or 2.5 per cent lower |

Table No. 2.

| | |
|---|---|
| 17 Illinois Geogolical Survey samples analyzed 6 months to 1 year after collection, compared with 16 similar samples analyzed within to weeks after collectson. | Older samples. Average 365 B. t. u. or 2 4 per cent lower. |

Table No. 3.

| | |
|---|---|
| 16 Illinois Geological Survey samples analyzed within 2 weeks after collection compared with 7 United States Geological Survey samples analyzed soon after collection. | Illinois Geological Survey samples. Average 29 B. t. u. or .2 per cent lower. |

## SUMMARY.

1. An exudation of combustible gases from coal occurs after the breaking out of the sample from the seam.

2. When coal is exposed on absorption of atmospheric gases, oxygen, nitrogen and carbon dioxide accompanies the extudation of hydrocarbons.

3. Samples of coal in most carefully sealed containers are subject to alteration, resulting in loss in calorific value.

4. The process of deterioration is probably due principally to the direct oxidation of the carbon, hydrogen and sulphur of the coal by the occluded oxygen or the free oxygen of the air. It is also due to the exudation of combustible gases and the absorption of non-combustible gases.

5. The rapidity or the extent of this alteration varies with different coals but is probably most active during the first two or three weeks after the coal is removed from the ground. From the present data, the deterioration of the sealed coal samples seems to be slow after a lapse of six months or a year. Studies now in progress may give more definite data on this point.

# Artificial Modification of the Composition of Coal.

(By S. W. Parr and C. K. Francis.)

## Introduction.

*Coalite*—During the year 1907 a good deal of notice has been given in the British press to a product which is of considerable interest in view of certain experiments carried on in the laboratory of Applied Chemistry of the University of Illinois for several years past.* The following description is abstracted from a series of articles published in The Iron and Coal Trades Review, during 1907.

The process for making coalite has been patented in the United States, England and Germany. The British patent claims that the method consists in subjecting any bituminous coal to a temperature approaching 800° F. (426° C.) for about eight hours, or until the illuminating gas ceases to be evolved, in closed rectangular retorts, placed vertically in a gas fired furnace. When illuminating gas ceases to be evolved, and the mass is substantially free from tarry components, the heat is suddenly arrested by the introduction of steam, and the product removed from the retort. Each retort has a capacity of 15 cwts., and each charge yields about 11 cwts. of coalite. This may vary with different coals, but the yield will generally be about 70 per cent. According to the claims made for coalite, the yield and by-products will compare favorably with that obtained in the manufacture of illuminating gas.

The analysis of coalite is stated to be:

| | |
|---|---|
| Ash | 7 per cent |
| Volatile matter | 12 per cent |
| Fixed carbon | 80 per cent |
| Sulphur | 1 per cent |
| B. t. u. | 13500 |

The samples which have been on exhibition in London resemble coke in appearance and combustion, burning with a bluish flame. The English press seems to be unfavorably disposed towards coalite, probably on acount of the claims made by the promoters, that it is superior to any form of steam coal, and because of the diligent efforts to float the stock of the company, which is capitalized at $275,000 with permission to increase to $10,000,000, thus giving many of the attributes of a mere stock-jobing enterprise. The total profit is estimated, in the prospectus

* Anthracizing of Bituminous Coal. State Geol. Survey, Illinois Bull, 4, p. 196.

at two and one-half million dollars a year from the production of 2,100,000 tons of coalite and the resulting gas, apart from other by-products.

The Scottish Smokeless Coal Co. claims to make from non-coking smalls, a fuel having an analysis practically the same as coalite. The Gas Light and Coke Co. of London advertise a smokeless fuel under the name of "Carbo." The South Metropolitan Gas Co. will probably place a similar product on the market. From these and other considerations, a serious question has been raised as to the validity of any patent intended to cover the process as outlined.

*Experiments at Urbana*—This mention is made of the main features involved in connection with "coalite" because of a certain resemblance in method to the experiments carried here. The lack of any detailed study of the reactions involved in the process, together with the value which such resulting facts would have, aside from their direct commercial bearing, furnish ample reason for a continuation of this work.

An account of these experiments was given in the Year Book for 1906. They were originally taken up with a view to the possible modification of bituminous coal in such a manner as to eliminate largely the constitutents which tend to produce smoke in combustion and the production of a material having the essential properties of anthracite or semi-anthracite coal. The results as tabulated last year showed a possible increase in the fixed carbon of 25 per cent and over. The experiments, however, were of a preliminary type and took no account of the composition of the evolved gases nor of the varying effects that might be produced by different kinds of atmosphere. A continuation of this line of work seemed warranted and the earlier tests pointed out, at least in regard to their main features, what conditions should be observed in further experiments.

The work already referred to, developed in a general way the type of apparatus needed and the conditions under which further tests should be made.

Mr. Deane Burns,* in his thesis investigation had made use of a small metal cylinder of six to eight grams capacity, which was brought under temperature control by being fitted into a hot air bath. With this device some attempt was made to govern the kind of atmosphere in which the distillation should proceed. In the tests herein recorded, a larger furnace with definite circulation of atmosphere was provided as in the description below.

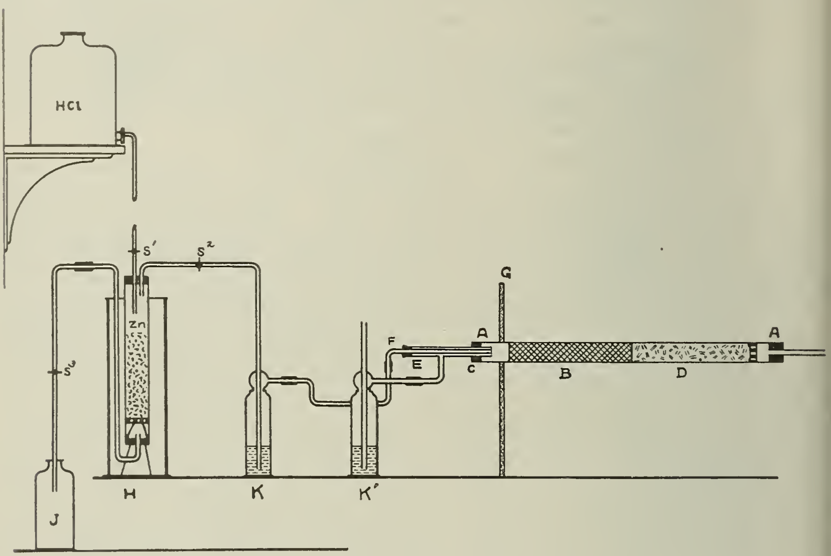
### LATER EXPERIMENTAL WORK—FIRST SERIES—NITROGEN ATMOSPHERE.

*Apparatus*—The first series of experiments was made in a non-oxidizing atmosphere in order to eliminate, as far as possible, those variables which would result from oxidation. While this would be an extreme condition, and one not possible as an industrial feature, for experimental purposes it would admit of the study of actual changes taking place as a result of heat alone. For this purpose, therefore, nitrogen, free from carbon dioxide and oxygen, was employed. This gas was prepared from air as suggested by Hulett.† The apparatus and amount of material was slightly modified, in order to

*Burns, Univ. of Ill. Thesis, Class 1907.
†Jour. Amer. Chem. Soc., vol. 27, p. 1415, 1905.

permit of easy observation of the process. As claimed by the author, it is not difficult by this method to prepare large quantities of nitrogen, and at a rapid rate, when once the operation is under control.

The essential parts of the appartus are shown in figure 5.




APPARATUS FOR PREPARING NITROGEN

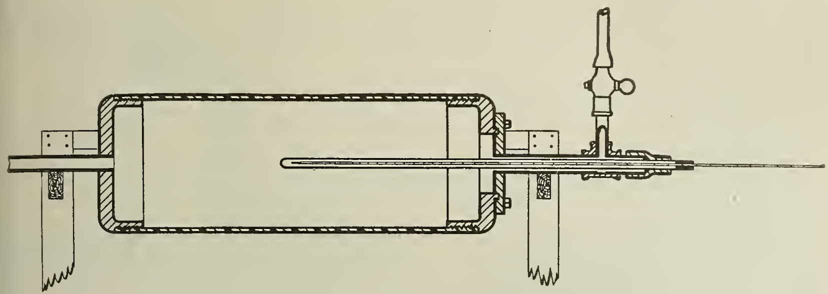
FIG. 5.

A. A. is an ordinary combustion tube, 2 cm. or over, in diameter, and 1 meter long; B is 40 cm. of loosely rolled copper gauze; D is 35 cm. of copper oxide, the wire or gauze form preferred; E is made from a piece of hard glass tubing; F is a small porcelain tube or pipe stem, a Rose crucible stem was used in our apparatus; G is a thick piece of asbestos board for protecting the stopper C from the heat; the wash bottles K and K′ are half filled with water and serve to indicate the speed with which air and hydrogen are being admitted. The generator H, devised by Messrs. McClure and Barker,* needs by little description. The reservoir for dilute hydrochloric acid is placed about 2 meters above the table, the flow being controlled by stopcock S′; J serves as a reservoir for the spent acid which siphons over from the generator.

The nitrogen was used as soon as possible after preparation, and when analyzed, was found to be free from hydrogen and carbon dioxide, with but a very slight trace of oxygen, which may have been due to oxygen dissolved in the water of the gasometer.

The apparatus used for the experiments on coal is shown in plate 7. It consists of an iron retort placed in an oven, which is encased in asbestos. An exit tube leads into two flasks, kept cold with running water, which serve for collecting the liquid products of distillation. These flasks, with their connections, were weighed before each experiment; the increase in weight was called water and oil. The quantities of water and oil were determined later by separation. Beyond these is shown the safety flask, used to check any backward flow of water from the gas bottles into the condenser flasks.

* Chem. Eng., vol. 6, p. 109 1907.



RETORT FOR LOW-TEMPERATURE COAL DISTILLATION

FIG. 6.

The details of the retort used are shown in figure 6.

Temperatures were indicated by a mercury thermometer, with carbon dioxide under pressure above the mercury to admit of high temperature readings. This thermometer was protected by a glass tube, which was sealed into the retort by means of a piece of thick rubber tubing, being first pulled over it, and then over the end of the retort as shown in Figure 6. This system permitted the thermometer to be withdrawn for readings without disturbing the atmosphere in the retort.

*Material*—The bituminous coal used for this series of tests, was a sample of No. 7 coal from Williamson Co., Ill., (Carterville), and was marked No. 686, for identification in this laboratory. It had the following composition:

| No. 686. | Moist coal. | Dry coal. |
|---|---|---|
| Moisture | 6.53 | ............ |
| Ash | 7.76 | 8.30 |
| Volatile matter | 33.86 | 36.23 |
| Fixed carbon | 51.85 | 55.47 |
| Sulphur | 2.10 | 2.24 |
| B. t. u. per lb | 12,380 | 13,244 |
| B. t. u. per lb. ash water and sulphur free | ............ | 14,567 |

The dry ash, 8.30 per cent, as shown in the above table, was used as a standard condition for reference. The results of the proximate analyses were calculated to the dry basis by subtracting the percentage of moisture from 100, dividing the remainder into each amount and multiplying by 100 to read as per cent.

$$\frac{51.85\%\ \text{Fixed Carbon}}{(100 - 6.53)} \times 100 = 55.47\%\ \text{Fixed Carbon, Dry Basis.}$$

The formula for calculating the B. t. u. in terms of "corrected" ash and water free, i. e., ash, water and sulphur free basis,* may be expressed as follows:

$$\frac{\text{B. t. u.} - (\text{Weight of Sulphur} \times 4050)}{100 - (\text{Ash} + H_2O + \frac{5}{8}\,\text{S.}(} \times 100 = \text{B. t. u. per lb. unit coal.}$$

*Example*—

$$\frac{12380 - (.0210 \times 4050)}{100 - (7.76 + 6.53 + (\frac{5}{8} \times 2.10)} \times 100 = 14567 \text{ B. t. u. per lb. unit coal.}\dagger$$

*Mechanical Operation*—In preparing the sample for this series, a large quantity, about 40 pounds, of the air dried coal was crushed to buckwheat size, thoroughly mixed and divided into several portions, each lot being numbered to correspond with the test in which it was to be used.

The operation may be described as follows: The portion of coal, usually something over 2,000 grams, was placed in the retort. (Fig. 6).

The head of the retort was brought to place by the screws as shown, and a perfect seal secured by means of asbestos packing moistened with water. The apparatus, when connected, was thoroughly tested for leaks. In order to wash out the air, and to furnish an inert atmosphere, nitrogen was admitted until the gas at the exit tube would no longer support combustion; usually about 15 liters were required. Heat was then applied and the evolved gases collected in the gas holders, two of these always being attached, one cut off and held in reserve to be used in case there should be an extra amount of gas suddenly evolved or when the first was filled.

The retort was turned by hand every minute or two during the operation. The exit tube was polished and coated with powdered graphite in order to permit of its turning readily within the rubber tubing which lead to the condenser flasks.

When the experiment was completed, the retort was disconnected from the rest of the apparatus, then sealed with rubber stoppers and slowly cooled. The gas holders and the flasks were closed by means of the pinch cocks shown in the illustration, plate 7.

*Analytical Methods*—The gas holders were sealed when full, the time and temperature recorded and the bottle marked. The amount of gas was easily obtained as the capacity of each bottle had been determined. Each sample was carefully analyzed according to the methods devised by Hempel.‡

The coal before treatment and also the residue were analyzed according to the method recommended by the committee on coal analysis appointed by the American Chemical Society.§ The samples of coal, as freshly taken, were air-dried for twenty-four hours, carefully sampled, then powdered sufficiently to pass a 60 mesh sieve. The method for moisture was slightly modified as follows: 1 gram was weighed out into a small bottle, especially designed for the purpose,¶ provided with a ground glass stopper which fits over the outside edge of the bottle, thus preventing loss of material by contact with the ground glass surface when the dry coal is brushed out for the ash or other determination. The bottle and contents were placed in a toluene bath, the cover removed, and the sample dried for one hour at 105° C., the cover replaced, and put in a desiccator until cold.‖

The following table shows the conditions under which each test was conducted:

---

*Jour. Amer. Chem. Soc., vol. 28, p. 632. 1906. Trans. Amer. Inst. Min. Eng., Bulletin No. 19, p. 49, 1908.

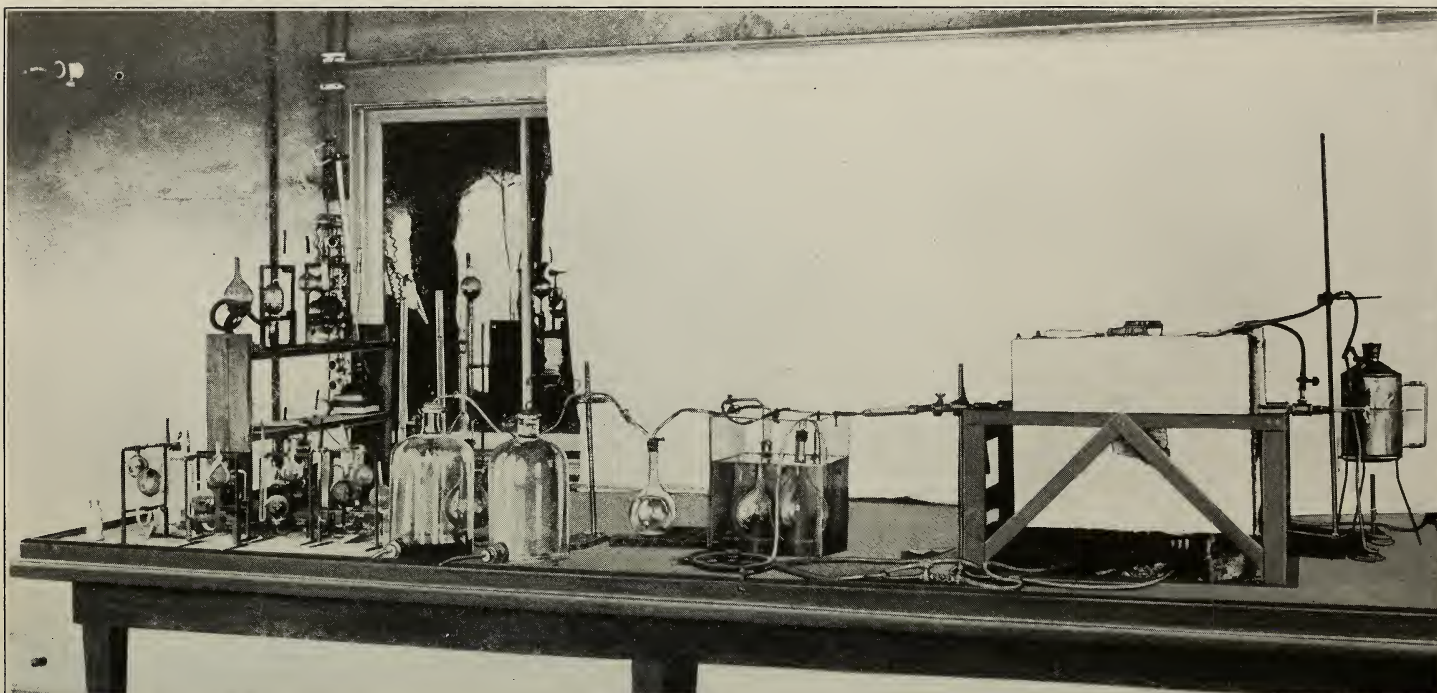
†The expression "Unit Coal" is here used to denote the ash, water and sulphur free material.

‡Hempel's Gas Analysis, Trans, Dennis.

§Jour. Amer. Chem. Soc., vol. 21, p. 1130, 1899.

¶State Geol. Surv. Illinois, Bull. 4, p. 195, 1907.

‖It may be advisable to mention that, if the fuming sulphuric acid for the determination of illuminants shows a tendency to crystallize, slight warming, or better, dilution with water, will prevent this. Experiments seem to indicate that, if this diluted acid will produce fumes and a hissing sound when added to water, it will absorb the heavy hydrocarbons. It may be of sufficient strength even when diluted with one third its volume of water.



Furnace for the distillation of coal.

TABLE NO. 1.

*Test Conditions—Carterville Coal, Nos. 686 and 791—Atmosphere of Nitrogen.*

| Test Number. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Weight of coal in grams | 2247 | 2278 | 2250 | 2465 | 2371 | 2400 | 2120 | 2500 |
| Size of coal | Buckwheat | Buckwheat | Buckwheat | Buckwheat | Buckwheat | Buckwheat | Buckwheat | Nut |
| Period of observation | 2 hrs. | 2 hrs., 20 min. | 2 hrs. | 1 hr., 50 min. | 4 hrs. | 6 hrs. | 3 hrs. | 6 hrs. |
| Total time of treatment | 3 hrs. | 3 hrs., 10 min. | 3 hrs. | 2 hrs., 40 min. | 4 hrs., 40 min. | 7 hrs., 30 min. | 5 hrs., 20 min. | 8 hrs. |
| Lowest temperature | 214°C | 221° | 204° | 243° | 208° | 339° | 369° | 364° |
| Highest temperature | 286° | 310° | 299° | 358° | 316° | 375° | 431° | 400° |
| Average temperature | 270° | 292° | 277° | 336° | 299° | 367° | 402° | 381° |

The figures at the top of the columns indicate the number of the test. The period of observation is the time during which the heat was maintained as near as possible, at the desired temperature. The total time of treatment includes the period of observation and the time required to bring the apparatus up to the desired temperature. The highest and lowest temperatures indicate the extremes which were recorded during the period of observation.

In the tables below, No. 2a and 2b, the actual values of the resulting product are given, in comparison with the values for the original coal, in order to show the entire alterations which have occured.

## TABLE NO. 2a.

*Proximate Analyses of the Residue Compared with that of the Original Coal.*

Sample No. 686—Atmosphere of Nitrogen.

| | Original Coal. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Average temperatures | .......... | 270° | 292° | 277° | 336° | 299° | 367° | 402° |
| Moisture | 6.53 | 1.79 | 1.01 | 1.53 | 1.44 | 1.00 | .70 | 1.25 |
| Ash | 7.76 | 8.71 | 8.85 | 8.85 | 8.96 | 8.48 | 9.20 | 10.85 |
| Volatile matter | 33.86 | 33.93 | 33.58 | 34.52 | 30.37 | 34.13 | 25.34 | 19.95 |
| Fixed carbon | 51.85 | 55.57 | 56.56 | 55.10 | 59.23 | 56.39 | 64.76 | 67.95 |
| Sulphur | 2.10 | 2.03 | 2.08 | 2.08 | 1.56 | 1.98 | 1.98 | 1.72 |
| B. t. u | 12380 | 12946 | 13092 | 12980 | 13232 | 13282 | 13133 | 12836 |

## TABLE NO. 2b.

*Proximate Analysis of the Residue Compared with that of the Origin[al] Coal.*

Sample No. 791—Atmosphere of Nitrogen.

| | Original Coal. | Test No. 8. |
|---|---|---|
| Average Temperature | .............. | 381 |
| Moisture | 6.38 | 0.44 |
| Ash | 8.92 | 10.40 |
| Volatile Matter | 34.64 | 23.73 |
| Fixed Carbon | 50.06 | 65.43 |
| Sulphur | 2.09 | 1.51 |
| B. T. U | 12443 | 13192 |

In the above tables, No. 2a and 2b, the advantages exhibited in the product, in comparison with the original coal, are exaggerated by reason of the large loss of moisture. It is, therefore, misleading as an index of actual chemical transformations, but it does give a correct relative indication of values in the treated condition. For example, the resulting product, in tests 4, 5, 6 and 8, show a relative increase in B. t. u. of from 6 to 7 per cent.

In order to arrive at an appreciation of the actual changes that have taken place, the various constituents must be calculated to some common unit for comparison. This has been done in tables No. 2a and 3b, where the unit employed has been the original ash content of the coal, when reduced to the dry or water free basis.

## TABLE No. 3a.

*Resulting Constituents Compared with Unit Ash, Dry Basis.*

Atmosphere of Nitrogen.—Carterville Coal, Sample No. 686.

| | Values Before Heating. | Test Numbers. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Average Temperature | ........ | 270° | 292° | 277° | 336° | 299° | 367° | 402° |
| Ash | 8.30 | 8.30 | 8.30 | 8.30 | 8.30 | 8.30 | 8.30 | 8.30 |
| Volatile Matter | 36.23 | 32.33 | 31.49 | 32.38 | 28.13 | 33.38 | 22.86 | 15.26 |
| Fixed Carbon | 55.47 | 52.95 | 53.05 | 51.68 | 54.87 | 55.05 | 58.43 | 51,98 |
| Sulphur | 2.24 | 1.92 | 1.95 | 1.93 | 1.45 | 1.94 | 1.83 | 1.32 |
| B. T. U | 13244 | 12366 | 12278 | 12173 | 12257 | 13000 | 11847 | 9819 |
| B. T. U. on Unit Coal‡‡ Basis. | 14567 | 14583 | 14639 | 14601 | 14859 | 14783 | 14689 | 14702 |

‡‡By "Unit Coal" is here meant the ash and water free basis corrected for sulphur as on p. 180.

## TABLE No. 3b.

*Resulting Constituents Compared with Unit Ash, Dry Basis.*

Atmosphere of Nitrogen.—Carterville Coal, Sample No. 791.

| Test No. 8. | Values before heating, dry coal. | Values after heating, referred to unit ash. |
|---|---|---|
| Average Temperature | ........... | 381° |
| Ash | 9.52 | 9.52 |
| Volatile Matter | 37.00 | 21.70 |
| Fixed Carbon | 53.47 | 59.88 |
| Sulphur | 2.23 | 1.38 |
| B. T. U | 13290 | 12076 |
| B. T. U. unit coal basis | 14819 | 14887 |

In these tables, 3a and 3b, it is assumed that, by taking a unit ash, for example 8.30 per cent, or the amount present in the oven dry coal before treatment, and calculating the relative amounts of the several constituents to this unit as a basis, an indication would thus be made of the actual

changes produced in the several initial values. Thus, at all temperatures, there is an actual decrease in the volatile matter which becomes marked in the higher temperature, viz., in tests No. 4, 6, 7 and 8, or from a range of 375 to 400 degrees centigrade.*

In tests 6 and 8, a positive increase of fixed carbon is shown, while in all cases a reduction in the heat values is indicated. This reduction is accounted for by the hydrocarbon values represented in the gaseous and oil products of distillation. Especial attention should be directed to the last line showing the heat values calculated to the unit coal basis. These values show a consistent increase throughout. A tentative explanation is offered in that the oxygen and nitrogen compounds of the volatile matter have been more largely driven off than was the case with the hydrocarbon compounds. If the loss in volatile matter as shown had been chiefly that of the marsh gas ($CH_4$) series, a reduction in heat values for unit coal must result. If, however, the loss is made up of water of composition, $H_2O$, phenol, $C_6H_5OH$, etc., there would be a relative increase in the heat content of the residual coal. Further, the weight of water condensing in the flasks and separated from the oil, showed in each test an increase over the possible amount which could come from the free water present. The increase amounted to 3 per cent in test No. 4, 4½ per cent in test No. 6, and a little less than 3 per cent in test No. 7. These figures must represent the percentage of decrease in the water of composition. A loss of 2 per cent in this constituent would raise the B.t.u. factor, referred to the unit coal basis, from 14567 to 14864. This would seem to warrant the conclusion that a loss of water of composition occurs. This is an important point to further substantiate, as it is a fundamental feature of this investigation to develop, as nearly as may be, the conditions which govern the various decomposition processes.

In order to arrive at a further appreciation of the actual changes that have taken place, the alterations in the several constituents have been calculated to a percentage gain or loss of their original values as presented in Table No. 4, as below. From the table, it will be seen that the actual loss in volatile matter has been accompanied in the higher temperatures, as shown in tests 6 and 8, with an actual increase of fixed carbon. The decrease in the heat units of the product is not an actual loss but is represented by corresponding values in the combustible gases, as shown in a succeeding table, No. 5.

## TABLE NO. 4.

*Loss or Gain of Constituents Calculated as Percentage of Original Values for Each.*

Samples No. 686 and 791—Atmosphere of Nitrogen.

| Number of test. | | Volatile matter. | Fixed carbon. | Sulphur. | B. T. U. | Weight ash and water free. | Yield per 100 lbs. dry coal. | Average temperature. |
|---|---|---|---|---|---|---|---|---|
| 1 .......... | Loss..... | 10.75 | 4.56 | 14.28 | 6.63 | 7.00 | 93.58 | 270°C. |
| 2 .......... | Loss..... | 13.08 | 4.38 | 12.94 | 7.29 | 7.81 | 92.84 | 292° |
| 3 .......... | Loss..... | 10.63 | 6.85 | 13.85 | 8.09 | 8.33 | 92.36 | 277° |
| 4 .......... | Loss. | 22.35 | 1.08 | 35.27 | 7.45 | 9.49 | 91.30 | 336° |
| 5 .......... | Loss..... | 7.86 | .76 | 13.39 | 1.84 | 3.57 | 96.73 | 299° |
| 6 .......... | Loss..... | 36.90 | .......... | 15.62 | 10.54 | 11.35 | 89.59 | 367° |
| | Gain..... | .......... | 5.34 | .......... | .......... | .......... | .......... | .......... |
| 7 .......... | Loss..... | 57.88 | 6.30 | 41.11 | 25.86 | 26.68 | 75.54 | 402° |
| 8 .......... | Loss.... | 41.35 | .......... | 38.12 | 9.14 | 9.84 | 91.10 | 381° |
| | Gain..... | .......... | 11.99 | .......... | .......... | .......... | .......... | .......... |

*Centigrade degrees are used throughout in this discussion. $°C \times 1.8 + 32 = °F$.

The character of the gas may be judged from the analyses given below, Table No. 5. No attempt was made to collect all the gas produced before test No. 6. Although samples were taken and analyzed, they were not considered representative of the total volume, so are not given. The figures given below were obtained by averaging the analyses of each portion evolved.

## TABLE NO. 5.

*Composition of Gas as Shown by Averaging Analyses of Portions Given Off.*

| Test number. | 6 | 7 | 8 |
|---|---|---|---|
| Temperature | 367°C. | 402° | 381° |
| Period of observation | 6 hrs. | 3 hrs. | 6 hrs. |
| Carbon dioxide and hydrogen sulphide | 21.85 | 17.33 | 12.58 |
| Illuminants | 8.67 | 9.54 | 10.48 |
| Oxygen | 0.00 | 0.00 | 0.00 |
| Carbon monoxide | 8.42 | 7.66 | 6.96 |
| Methane | 2.52 | 32.66 | 28.07 |
| Hydrogen | 1.99 | 2 37 | 2.07 |
| Nitrogen | 56.54 | 29.97 | 39.50 |
| Volume of gas evolved | 47 Liters. | 50 Liters. | 45 Liters. |

### SECOND SERIES; STEAM ATMOSPHERE.

In this series, the atmosphere of nitrogen was replaced by one of steam. Presumably, this also would be a non-oxidizing atmosphere, but the opportunity to study the action of steam directly at the temperatures employed, as well as to compare the action with that where nitrogen was used, was deemed of sufficient importance to arrange for this series as given below.

The apparatus was set up as shown in the illustration, plate 7. The steam was generated from distilled water, and conducted directly into the retort, which was maintained, as before, at the desired temperature by means of gas burners, the retort being frequently turned on its axis. The coal treated was from the same mine as that used for the previous series. The composition of the samples is shown by the following analysis:

| No. 1056. | Moist coal. | Dry Coal. |
|---|---|---|
| Moisture | 3,28 | ............ |
| Ash | 8.44 | 8.72 |
| Volatile matter | 36.83 | 38.07 |
| Fixed carbon | 51.45 | 53.19 |
| Sulphur | 2.49 | 2.57 |
| B. T. U. | 12868 | 13304 |
| B. T. U. unit coal basis | ............ | 14605 |

The conditions under which this test was made are indicated below.

| Coal No. | Test No. | Size of coal. | Weight of coal. | Period of observation. | Total time of treatment. | Lowest temperature. | Highest temperature. | Average temperature. |
|---|---|---|---|---|---|---|---|---|
| 1056 | 1 | Buckwh'at | 2400 gr. | 2 hrs. | 3 hrs., 40 min. | 366° | 386° | 381° |

## TABLE NO. 6.

*Constituents of the Residue Compared with those of the Original Coal.*

Atmosphere of Steam. Temperature 381°C.

| | PROXIMATE ANALYSES. | | UNIT ASH BASIS. | |
|---|---|---|---|---|
| | Before. | After. | Before. | After. |
| Moisture | 3.28 | 0.28 | ........ | ........ |
| Ash | 8.44 | 9.64 | 8.72 | 8.72 |
| Volatile matter | 36.83 | 28.51 | 38.07 | 25.78 |
| Fixed carbon | 51.45 | 61.57 | 53.19 | 55.79 |
| Sulphur | 2.49 | 2.37 | 2.57 | 2.14 |
| B. T. U. | 12868 | 13221 | 13304 | 11959 |
| B. T. U. unit coal bases | ........ | ........ | 14605 | 14813 |

Those results are very similar to those obtained in an atmosphere of nitrogen. It is to be noted that there is a relative increase in fixed carbon (51.45 to 61.47), as also an actual increase (53.19 to 55.79). The relative heat values are higher after treatment, but, when calculated to unit ash (8.72%) the value is lower; the loss being represented by the hydrocarbons of the gases distilled. An interesting verification of the previous results is also shown in the B.t.u. calculated to unit coal. Here, again, it seems probable that the loss in volatile matter was greater in non-combustible constituents than in hydrocarbons. No approximation could be made in this test, of the amount of water of composition recovered, because of the additional water due to the condensation of the steam. The additional weight of condensation would represent 8.30 per cent of water. In further experiments with a steam atmosphere, it may be possible to make record of the amount of condensation from the steam introduced.

## TABLE NO. 7.

*Analysis of Gas Evolved from the Coal under an Atmosphere of Steam.*

| Coal No. | Temperature. | Period of obsevat'n | Hydrogen sulphide. | Carbon dioxide | Oxg'ny | Illuminants. | Carbon monoxide. | Methane. | Hydrogen. | Nitrogen. | Volume of gas. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1056 | 381° | 2 hrs. | 20.30 | 12.10 | 0.80 | 7.30 | 9.60 | 20.60 | 0 | 29.30 | 37L. |

### THIRD SERIES: OXYGEN ATMOSPHERE.

The operation was the same as in the previous series, except that an atmosphere of pure oxygen was supplied during the entire period of heating.

The coal treated was of the same character as No. 686, and from the same mine, with the composition shown in the following analysis:

| No. 791. | Moist Coal. | Dry Coal. |
|---|---|---|
| Moisture | 6.13 | ........ |
| Ash | 8.27 | 8.81 |
| Volatile matter | 34.59 | 36.84 |
| Fixed carbon | 51.01 | 54.21 |
| Sulphur | 2.06 | 2.19 |
| B. T. U. per lb | 12443 | 13290 |
| B. T. U. unite coal basis | ........ | 14819 |

The following table shows the conditions under which this series was conducted.

## TABLE NO. 8.

*Test Conditions Carterville Coal. Sample No. 791.*

Atmosphere of Oxygen.

| Test number. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Weight of coal | 2350 gms. | 2200 | 2000 | 2350 |
| Size of coal | Buckwheat. | Buckwheat. | Buckwheat. | Buckwheat. |
| Period of observation | 3 hrs. 10 min. | 4 hrs. | 4 hrs. 20 min. | 4 hrs. |
| Total time of treatment | 4 hrs. 20 min. | 5 hrs. 15 min. | 3 hrs. 30 min. | 6 hrs. |
| Lowest temperature | 249° | 328° | 346° | 349° |
| Highest temperature | 290° | 358° | 404° | 402° |
| Average temperature | 279° | 346° | 379° | 375° |

The composition of the coal before and after treatment in an atmosphere of oxygen under the conditions as indicated, is shown in the table below:

## TABLE NO. 9.

*Proximate Analysis of the Residue Compared with the Original Coal Sample 791.*

Atmosphere of Oxygen.

| TEST NUMBER. | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| | Before. | After. | Before. | After. | Before. | After. | Before. | After. |
| Average Temperature | ........ | 279° | ........ | 346° | ........ | 379° | ........ | 375° |
| Moisture | 6.13 | 0.82 | 5.99 | 0.82 | 5.97 | 0.75 | 5.03 | 0.46 |
| Ash | 8.27 | 8.61 | 8.26 | 8.90 | 8.01 | 9.67 | 8.10 | 9.68 |
| Volatile Matter | 34.59 | 35.06 | 36.01 | 30.80 | 35.19 | 21.25 | 34.01 | 25.27 |
| Fixed Carbon | 51 01 | 55.51 | 49.74 | 59.48 | 50.83 | 68.33 | 52.86 | 64.59 |
| Sulphur | 2.06 | 2.07 | 1.98 | 1.92 | 2.04 | 1.94 | 2.07 | 2.25 |
| B. T. U | 12565 | 13027 | 12600 | 13251 | 12600 | 13152 | 12750 | 13217 |

A feature to be noted in this series is the fact that, at a temperature of 279°C, only a small amount of decomposition has taken place, or, in other words, the change in the constituents is about that which would result from the removal of the moisture. At 346°, as in test No. 2, a positive decomposition has occurred. It would seem, moreover, that oxidation had played a considerable part in the changes, as may be inferred by a reference to the composition of the gases from this test, shown in table No. 11. The same statements may also be made in connection with tests Nos. 3 and 4.

## TABLE NO. 10.

*Resulting Constituents Compared with Unit Ash, Dry Basis.*

Atmosphere of Oxygen.

| TEST NO. | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| | Before. | After. | Before. | After. | Before. | After. | Before. | After. |
| Average Temperature | ........ | 279° | ........ | 346° | ........ | 379° | ........ | 375° |
| Ash | 8.81 | 8.81 | 8.78 | 8.78 | 8.52 | 8.52 | 8.52 | 8.52 |
| Volatile Matter | 36.84 | 35.87 | 38.30 | 30.38 | 37.42 | 18.72 | 35'81 | 22.20 |
| Fixed Carbon | 54.21 | 56.80 | 52.90 | 58.69 | 54.05 | 60.20 | 55.66 | 56.85 |
| Sulphur | 2.19 | 2.00 | 2.10 | 1.88 | 2.16 | 1.71 | 2.17 | 1.98 |
| B. T. U | 13385 | 13330 | 13403 | 13072 | 13399 | 11588 | 13425 | 11633 |
| B. T. U. unit coal basis | 14819 | 14497 | 14813 | 14788 | 14768 | 14793 | 14800 | 14838 |

In this table, as in tables No. 3a and 3b, a unit ash is used as the basis of comparison in order to show the actual variation produced in the several factors. Since the samples were not identical, a slight variation in ash makes it necessary to compare the "before" and "after" values for each test. It is interesting to note that in an atmosphere of oxygen, the same general characteristics are evident as enumerated under series one and two. This additional fact is to be noted. An examination of the gas values as given in table 11, shows a high percentage of $CO_2$ for tests Nos. 2, 3 and 4. This indicates a direct oxidation at the temperatures employed. The amount of oxidation would, perhaps, be in proportion to the volume of oxygen admitted. Experiments were therefore devised to test this feature as in series 4, following table No. 11.

## TABLE NO. 11.

*Composition of Gas as Shown by Averaging Analyses of Portions Given Off.*

Atmosphere of Oxygen.

| Test Number. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Temperature | 279° | 346° | 379° | 375° |
| Period of observation | 4 hrs. | 4 hrs. | $4\frac{1}{2}$ hrs. | 3 hrs. |
| Carbon dioxide and hydrogen sulphide | 5.25 | 20.80 | 12.73 | 13.84 |
| Illuminants | 0.00 | 2.50 | 3.53 | 4.24 |
| Oxygen | 13.80 | 10.40 | 9.27 | 7.68 |
| Carbon monoxide | 2.50 | 6.60 | 4.74 | 6.64 |
| Methane | 7.20 | 12.27 | 13. 68 | 15.16 |
| Hydrogen | 0.00 | 0.00 | 0.00 | 0.00 |
| Nitrogen | 71.25 | 47.43 | 56.05 | 52.44 |
| Volume of gas evolved | 12 Liters. | 23 Liters. | 50 Liters. | 45 Liters. |

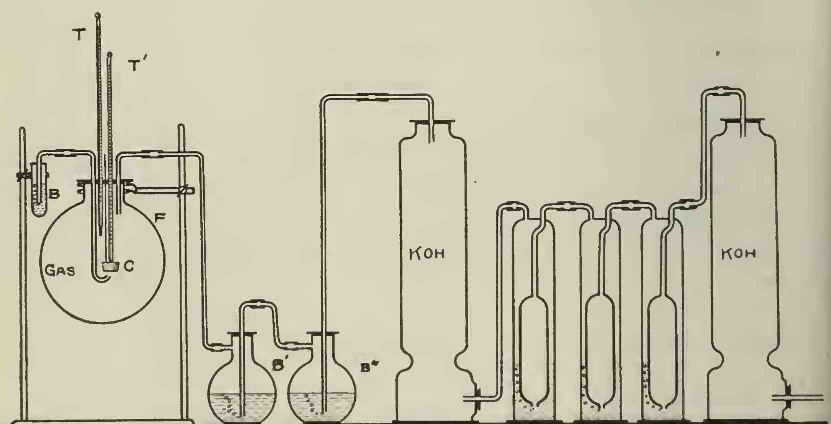
### FOURTH SERIES: OXIDATION EXPERIMENTS.

It was thought from a study of the previous series in an oxygen atmosphere, and the occasional sudden rise in temperature during test No. 4, that there was some internal oxidation of the coal. In order to verify this theory, at the end of that test with a temperature of 375°, the source of heat was removed and the retort cooled to 343°C. Oxygen was then admitted in excess to see if any chemical activity would result and show itself by a rise in temperature. The temperature at once rose to 349° and copious fumes were noticed in the exit tube. Upon opening the retort, the glass tube used to protect the thermometer was found to have been fused at a point just opposite the oxygen inlet. These facts suggested a series of experiments to determine, if possible, the reason for such rapid oxidation and the accompanying rise in temperature.

*Apparatus*—The apparatus devised for this series is shown in Figure 7, and, as may be seen, consisted of two towers filled with solid potassium hydroxide, and three washing bottles partially filled with a 50 per cent potassium hydroxide solution. That this solution thoroughly removed any traces of carbon dioxide, which may have been contained in the oxygen, was proved by means of solutions of barium hydroxide in the two small flasks, B′ and B.″ A round 1500cc Jena flask, F, served as a heating chamber; a nickel calorimeter capsule, C, for holding the material to be tested, was firmly fixed in a loop of heavy iron wire and suspended in the flask. Two thermometers were

used, one, T, to indicate the temperature of the gas (oxygen), and the other, T′, was immersed in the coal within the capsule. The exit tube led the products into a test tube, B, containing a freshly prepared solution of barium hydroxide.

Normally, it would be expected that the temperature of the surrounding gas would be slightly higher than that of the coal, the loss by convection and poor conductivity being shown by a slightly lower reading of the thermometer inbedded in the coal. It is evident, therefore, that any relative rise in temperature, as shown by the thermometer T′, would be due to chemical activity within the capsule. By charting the log of readings, therefore, of these two thermometers, we have an index of the behavior of the coal. This plotting of the curves in the accompanying charts, therefore, shows at a glance the stages at which the changes occur; the crossing of the lines, or their relative directions, being due to the addition or removal of the exterior source of heat, or to the greater or less activity of the oxidation process within the coal. This further point, however, should be borne in mind, that the temperature readings of the coal are relative as indicating the average value for the mass, since the oxidation no doubt is greater at the surface of the material and the thermometer bulb must pass through zones of higher or lower temperature.




OXIDATION OF COAL
AND
TEMPERATURE MEASUREMENTS
FIG. 7.

*Procedure and Results*—The method of operation was as follows: Two grams of the coal were placed in the nickel capsule, and the thermometers, etc., adjusted as described. Oxygen was then admitted at the rate of approximately 150 bubbles per minute. The flask, F, was uniformly heated with a constantly moving Bunsen flame and readings of both thermometers recorded every minute. The first appearance of carbon dioxide was noted in the test solution, B. This test tube was changed with sufficient frequency to indicate whether or not the evolution of carbon dioxide was continuous. It served to show also variations in quantity, since it could easily be told by the rapidity of precipitation, whether the gas was increasing or diminishing in amount.

By referring now to the accompanying charts, the continuous line in each shows the reading for the surrounding gas, while the dotted line gives the readings for the mass of the coal in the capsule. It may be said, also, that the readings were taken at half minute and minute intervals, but, for purposes of the charts, since the direction of the curves were not altered thereby, two minute intervals are indicated.

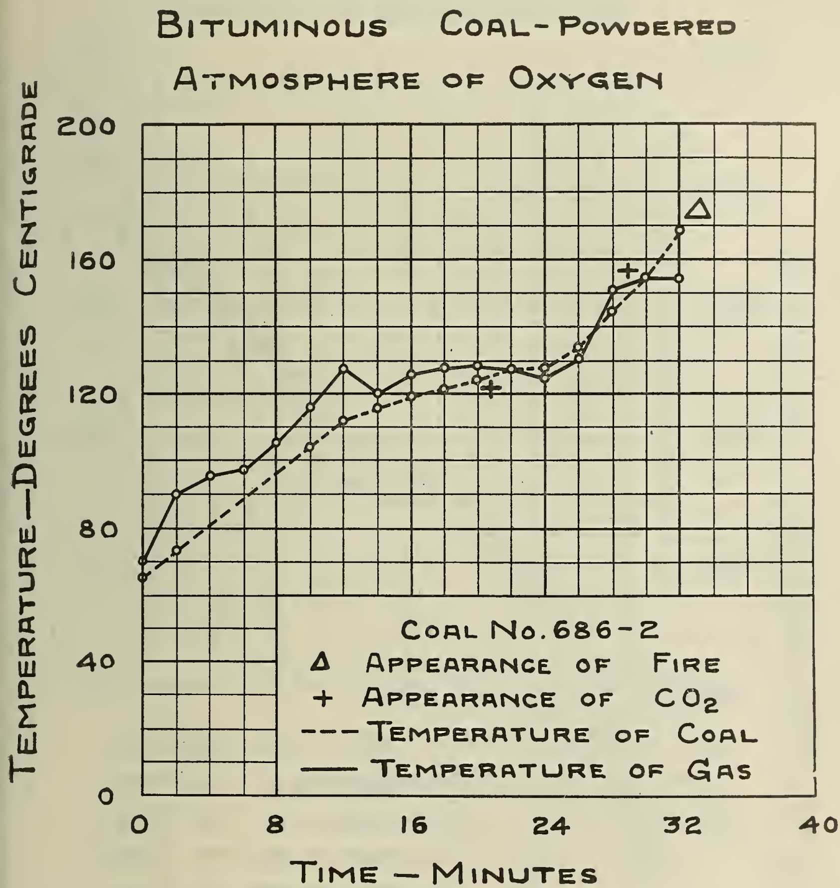



FIG. 8. Decomposition of Bituminous Coal, Powdered, in an Atmosphere of Oxygen.

The points to be noted are as follows: The crossing of the lines frequently occurs, showing that positive oxidation of the coal is taking place. If we examine in detail, for example Fig. No. 8, which is for a sample of Carterville coal in a finely pulverized form, at the point indicated by the first cross (+) or 125°, there was a positive appearance of carbon dioxide, as shown by the barium hydroxide solution. This appearance of carbon dioxide continued until a temperature of 155° was reached, when the chemical activity became so great as to cause a much more positive evolution of carbon dioxide and a very rapid rise of the thermometer T′; at 168°, as indicated by the delta △, the coal showed the presence of fire and, of course, thermometer observations could no longer be taken.

Figure 9 is a repetition of the previous tests as shown in Figure 8, except that the coal was of buckwheat size instead of powdered. Carbon dioxide first appeared at an indicated temperature of 112°, as shown by the first cross; at the second cross, which is intended to indicate the point where a

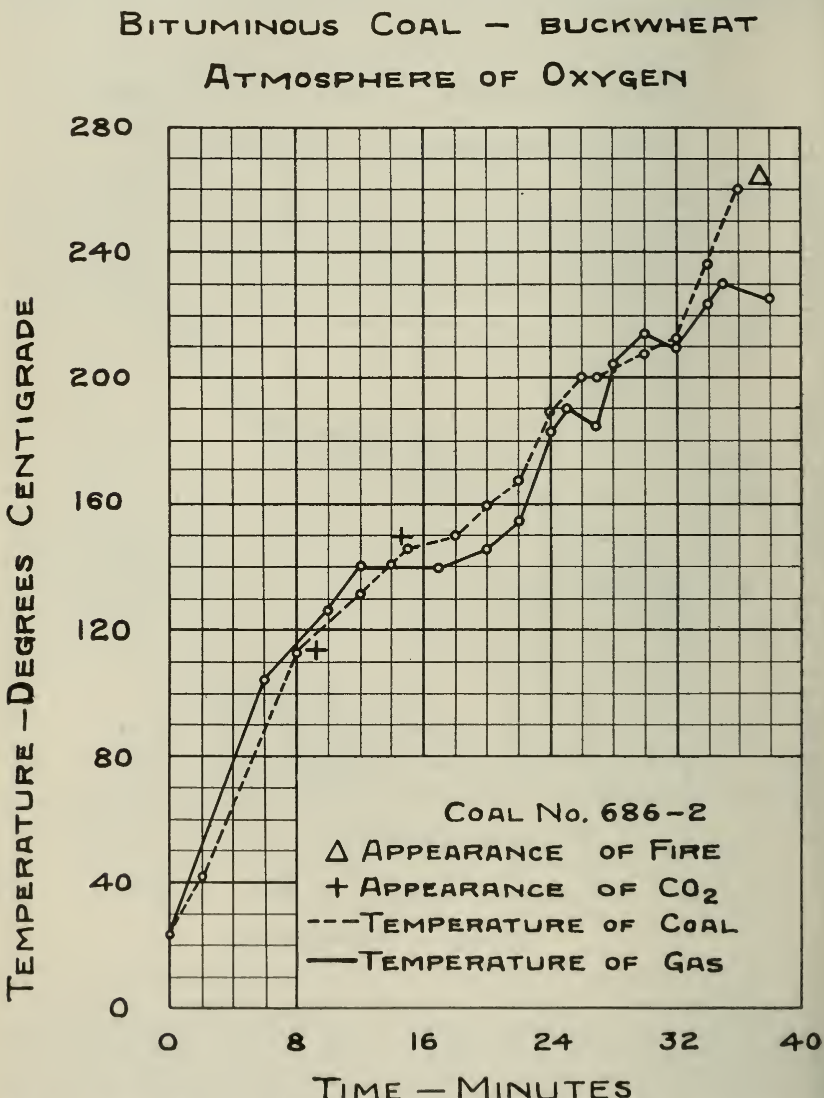



FIG. 9. Decomposition of Bituminous Coal, Buckwheat size in an Atmosphere of Oxygen.

very much more copious evolution of carbon dioxide appeared, the temperature reading was 147°. This rapid evolution of carbon dioxide continued over a much longer space, however, and the activity was not sufficiently great to show a red glow within the coal until a temperature of 258° was reached. This simply shows that the oxidation could proceed upon the finely divided coal more rapidly than upon the buckwheat size.

In Figure 10 a sample of Pittsburgh coal in the powdered form was employed. Here essentially the same phenomena were shown, both as to the appearance of carbon dioxide and as to the more rapid evolution of the same, though the point for the appearance of fire was slightly higher than

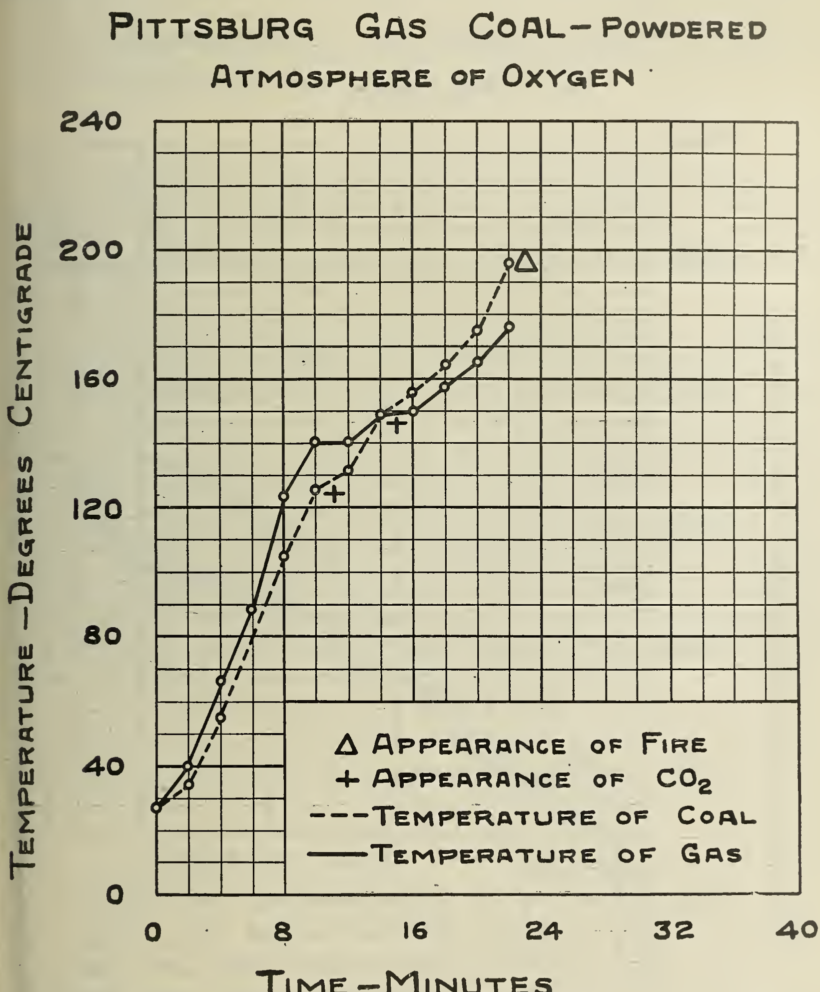



FIG. 10. Decomposition of Pittsburg Gas Coal in an Atmosphere of Oxygen

with the powdered bituminous coal of Figure 8. This suggests that the oxidation of hydrogen may also have a part in the chemical reactions involved, as being, perhaps, more readily available in coals of the strictly bituminous type.

In Figure 8 the results are shown upon a sample of powdered anthracite. The first appearance of carbon dioxide was again at 125°. At 135° there is a stronger evolution of carbon dioxide which continues with increasing rapidity as indicated by the more rapid rise in temperature up to 230°. At that point, a copious evolution of $CO_2$ occurred and ignition was indicated at 310°.

One point further should be noted in these tests. For convenience in charting, the results of any phenomena occurring between room temperature and those indicated have not been employed. In each instance, however, there was a slight appearance of carbon dioxide at about 30°; this disappeared

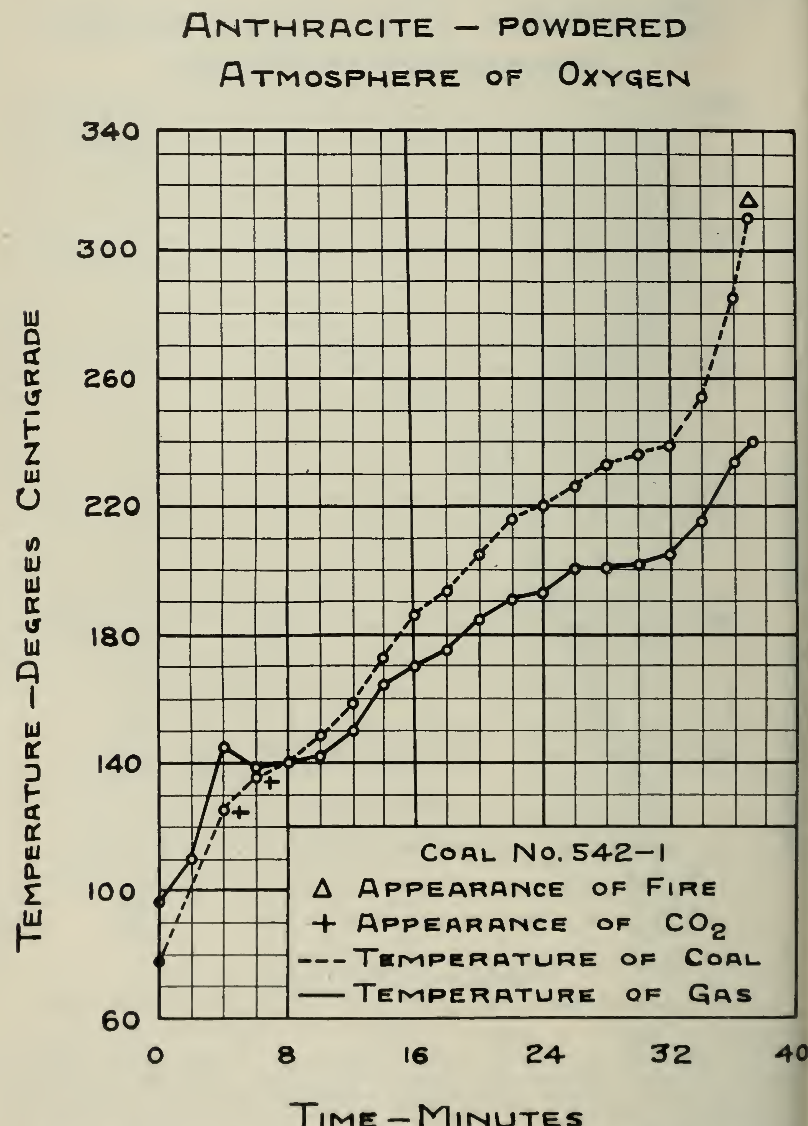



FIG. II. Decomposition of Anthracite Coal in an Atmosphere of Oxygen.

until a temperature of about 125° was reached. From this it is inferred tha a certain amount of carbon dioxide was occluded in the coal structure an was driven off at that temperature, and, therefore, this first appearance o that gas was not considered to be the point where oxidation began.

These charts are exceedingly interesting and show that rapid oxidation at a relatively low temperature. Morever, the kindling temperature is reached soon after active oxidation begins, depending to a considerable extent upon the oxygen supply and also upon the fineness of division, as well as the type of coal.

This study of the oxidation conditions explains, in the main, the reactions taking place in the larger masses of coal in the retort. It also bears directly upon other studies being carried on in this laboratory in connection with the weathering and spontaneous combustion of coal.

## SUMMARY.

The value of this investigation, from an industrial standpoint, can hardly be taken up until after a fuller development of all the facts involved. This work is now being continued and includes the determination of the extent and value of the by-products, such as ammonia, oils, gas, etc.

Concerning the coal residue, enough has already been developed to indicate that it would have a special value for domestic use and such industrial operations as require a smokeless fuel. While much of the volatile constituent remains, it has undergone a change which makes it not difficult to carry on combustion without the production of smoke. This fact is, perhaps, suggested by the rather close resemblance in composition to the so-called smokeless coals. Because of the very great ease with which this material may be broken down, it would require, in all probability, to be subjected to the briquetting process.

The gas given off is of high illuminating power while the liquid consists of oils without the presence of tar. Substances soluble in water, such as creosote, ammonia, etc., are present to a considerable extent. The availability and value of these by-products will be developed, it is hoped, in the further study of the problem.

# The Weathering of Coal.*

(By S. W. Parr and N. D. Hamilton.)

In coöperation with the Engineering Experiment Station of the University of Illinois there has been conducted during the year past a series of tests of the weathering of coals. The storing of coal is coming to be more and more a necessary practice in many industrial operations and the question of deterioration enters as a very vital factor in the case. That such deterioration occurs is conceded by everyone, but exact data as to its extent or information as to the conditions which retard or promote it are meagre. Storage plants with capacities ranging from 50,000 to 150,000 tons are becoming frequent. Each percent of deterioration in a storage heap of the smaller size represents a loss of the equivalent of 500 tons of coal. This is a serious proposition if true and the present series of experiments was devised for the purpose of developing, if possible, some of the facts connected with the matter.

Richter, after extended experiments in 1868, formulated an explanation for the weathering of coal, which does not seem to be disproven by more recent experimenters, to the effect that the weathering of coal is due to the absorption of oxygen, a part of which goes to the oxidation of carbon and hydrogen in the coal, and part is taken into the composition of the coal itself. We certainly need more definite information in order to formulate a final and satisfactory explanation of all the phenomena involved, but Richter's theory conforms to many of the known conditions and indicates the close relationship between the matter of deterioration and spontaneous combustion.

The experiments herein described had the disadvantage of being conducted upon a relatively small scale, in lots of ten to twenty pounds. It may be questioned whether deterioration in large heaps would be at a corresponding rate. Still, certain conditions seem to attend the process of weathering and a knowledge of these facts is a necessary preliminary to the more extensive study of the subject, which we hope to follow out.

Samples were obtained from several districts in the State so that conclusions might be generally applicable. The conditions under which the coals were studied were as follows: The starting point, of course, was the coal in its normal state; that is, as nearly as possible, corre-

*The greater portion of this article was published in *Economic Geology*, Vol. II, pp. 693-703. To the article as originally printed have been added additional data as indicated in the text. Readers will find the subject further discussed in Bull. 17, University of Illinois Engineering Experiment Station.

sponding to the condition existing when broken out of the seam. The time between the mining of the coal and the initial analysis varied somewhat, but the first series of tests was made as soon as possible after the mining of the coal. In the light of subsequent developments, greater stress should be put upon the early examination of samples to determine the initial condition. Even under the most careful disposition of samples in laboratory containers, a deterioration takes place which, while not strictly a weathering process, is still a large element in any study of the case and must be considered, if exact conclusions are to be available.

The coal used was of small lump or nut size, and each sample, of approximately one hundred pounds, was subdivided in order to subject the same kind of coal to various conditions. The conditions were to be continued through nine months and were as follows:

(*a*) Outdoor exposure.

(*b*) Exposure to a dry atmosphere at a somewhat elevated temperature, ranging between 85° and 120° Fahr.

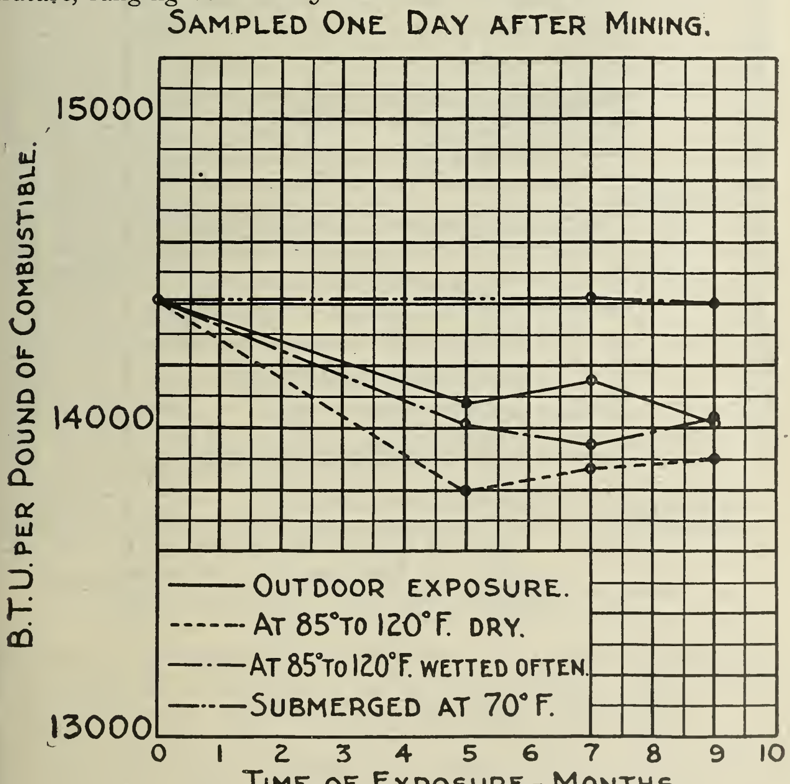



FIG. 12. Vermilion county "No. 7" coal; nut and slack.

(*c*) Under the same conditions as (*b*) so far as temperature was concerned, but to be drenched with water two or three times per week.

(*d*) Submerged in ordinary water at a temperature approximately 70°.

The periods for examination were divided as nearly as the work would permit into

1. The initial analysis of the fresh coal.
2. After exposure for five months.
3. After exposure for seven months.
4. After exposure for nine months.

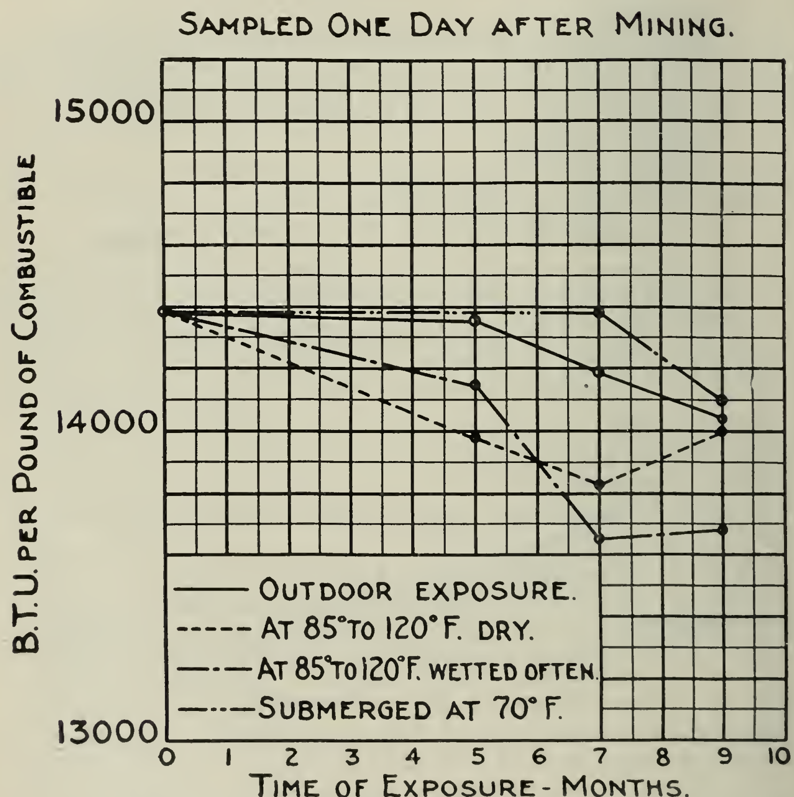



FIG. 13. Sangamon county "No. 5" coal; washed pea.

For the sake of comparison also the calorific values were determined under uniform conditions throughout by means of the Parr calorimeter and the results calculated to the ash- and water-free basis to eliminate, as far as possible, any variations in the process of sampling and to make, as far as possible, the different samples as well as the different lots comparable among themselves. The results for each sample are charted in the diagrams herewith. These charts are used by courtesy of the Engineering Experiment Station of the University of Illinois.

The possible sources of error in the methods here used are discussed elsewhere in this bulletin. It must be admitted that in these preliminary experiments they were not at all properly appreciated at the beginning. Indeed, it was in the course of this work that some of them were developed. The work is believed nevertheless to be sufficiently refined for qualitative results, and the curves being simple and consistent, may be accepted in that sense with some confidence. It would be well to reserve judgment as to detailed quantitative measurements until the completion of the more exact large scale tests now under way.

The diagrams show a distinct difference between the submerged coal and the samples exposed to the air. If we omit Fig. 13 it may be fairly said that no deterioration has taken place in the case of the submerged samples. It is not improbable that the initial value for the

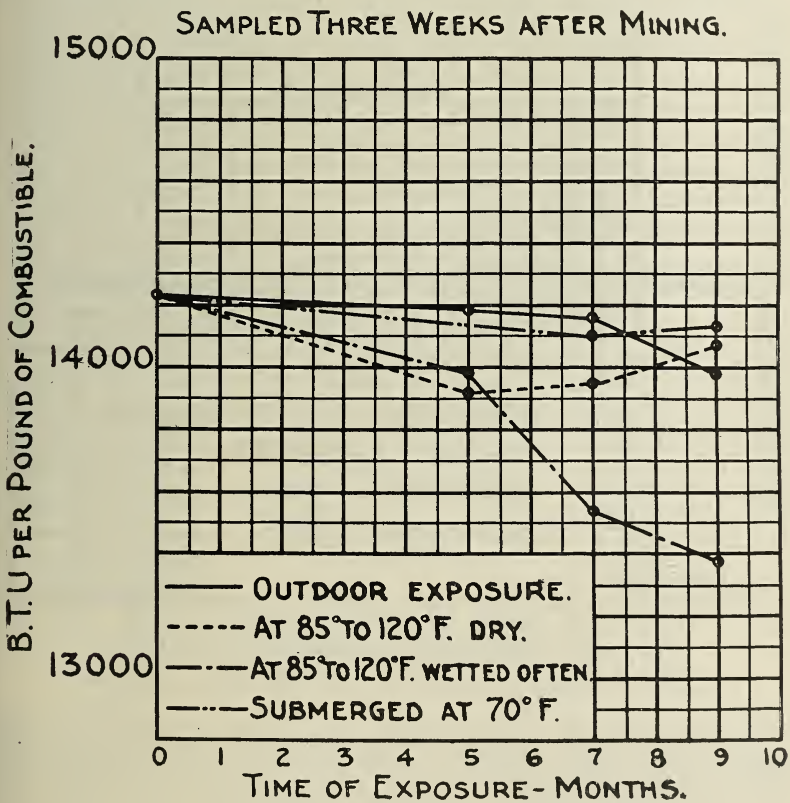



FIG. 14. Christian county "No 5" coal; nut and slack.

coal in some cases is too high, due to variations in sampling or less familiarity of the operator as to methods, etc. Indeed, as a whole, the values found for the submerged coal throughout the nine months did not vary by greater amounts than would be expected with the inevitable modifications due to sampling, temperature and other variables of manipulation or surroundings.

If we next consider the charting of the results obtained from samples subjected to outdoor exposure, we find wide variations in amount, but a uniformity as to the fact of marked deterioration. These samples were placed in shallow boxes on the nearly flat roof of a building and subjected alike to the changes of temperature and moisture common to the months from October to July. The treatment, therefore, was identical. The variations, which range from 2 to 10 per cent of loss in heat values must be ascribed to inherent properties of the coals

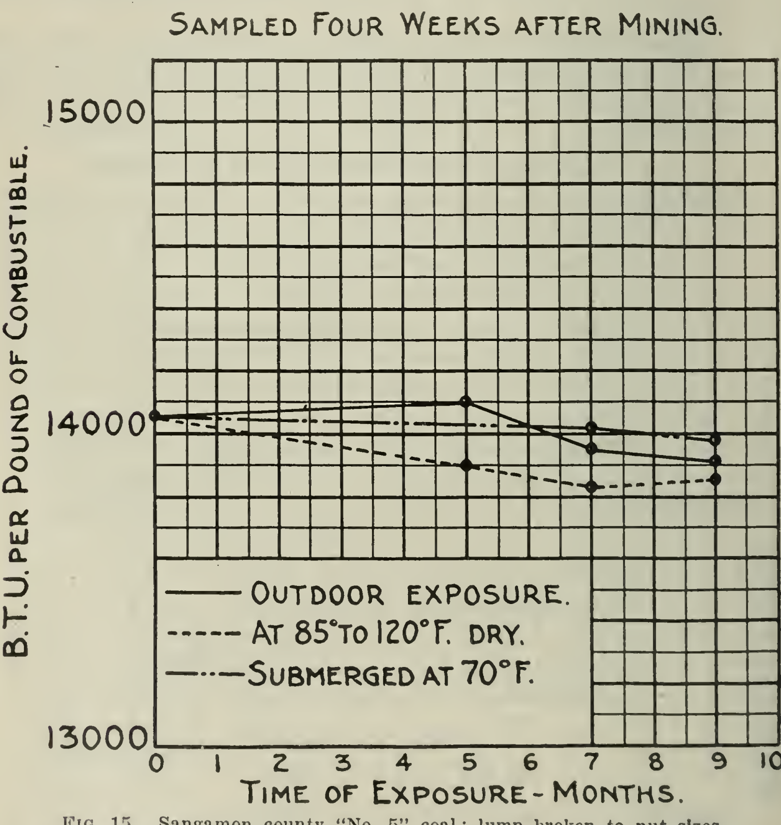



FIG. 15. Sangamon county "No. 5" coal; lump broken to nut sizes.

themselves. While all showed more or less of the tendency to disintegrate, they varied distinctly in the ease with which they would crumble under pressure.

If we consider next those samples represented by the dotted line or those subjected to a thoroughly dry atmosphere and at a slightly elevated temperature, we will find with but one exception, Fig. 16, a greater deterioration than in the case of outdoor exposure, and even in this exception the losses in both cases may be fairly said to be equal. Here is a rather unexpected result in that ordinarily a roof over coal

in storage is supposed to be preferable to open exposure. It is true that coal, in large masses, where heating might more readily occur as a result of wetting from rains, might behave differently; but, under the conditions, the results are as stated.

Finally, the samples subjected to high temperature with frequent wetting down, conform in general behavior to those samples exposed to outdoor influences. Where differences occur, as in Figs. 14 and 17, the deterioration is greater in the case of samples having the fre-

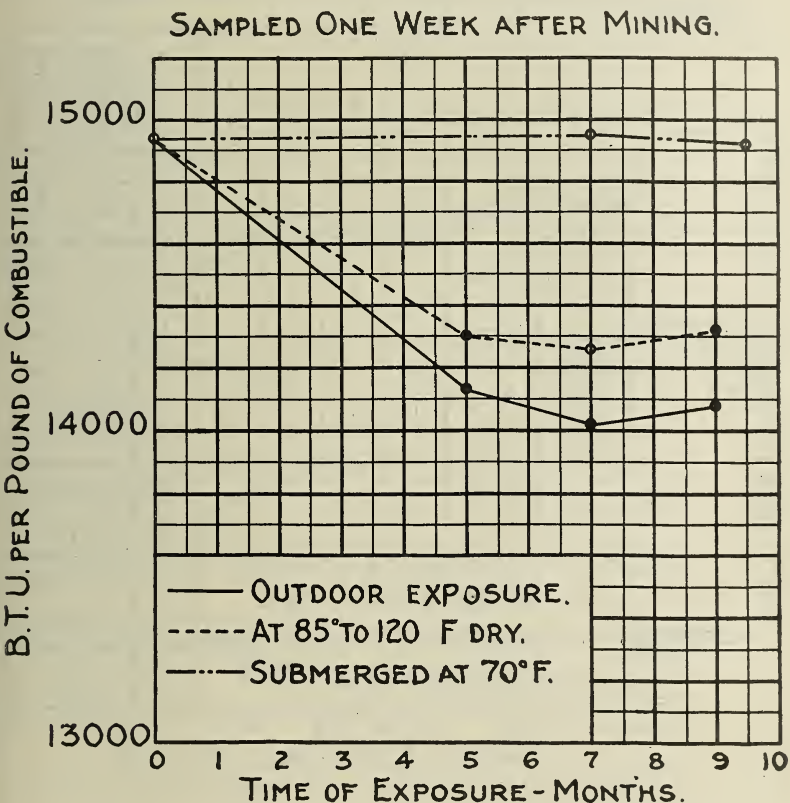



FIG. 16. Perry county "No. 6" coal; lump broken to nut sizes.

quent wetting and drying out process. Here, again, the results are undoubtedly variable in accordance with the variation of structure and composition of the coals themselves. In general, we would expect greater persistency of values in the dense and less friable coals and in those with less of iron pyrites throughout their texture.

Since charting the preceding results, additional data on the loss of fuel values have come to hand through the work of Mr. W. F. Wheeler, as follows: In collecting certain mine samples of coal for other experiments, opportunity was offered for procuring pillar coal

which had been exposed for twenty or more years. Since samples were to be taken from the working face of the seam, in the same mines, it was decided to take surface samples also from these old pillars. Two mines were thus sampled and the results are included in the tables below, Nos. 1 to 4. It will be seen that the losses in value are still within the extremes of variation shown by the weathering tests as illustrated in the preceding tests.

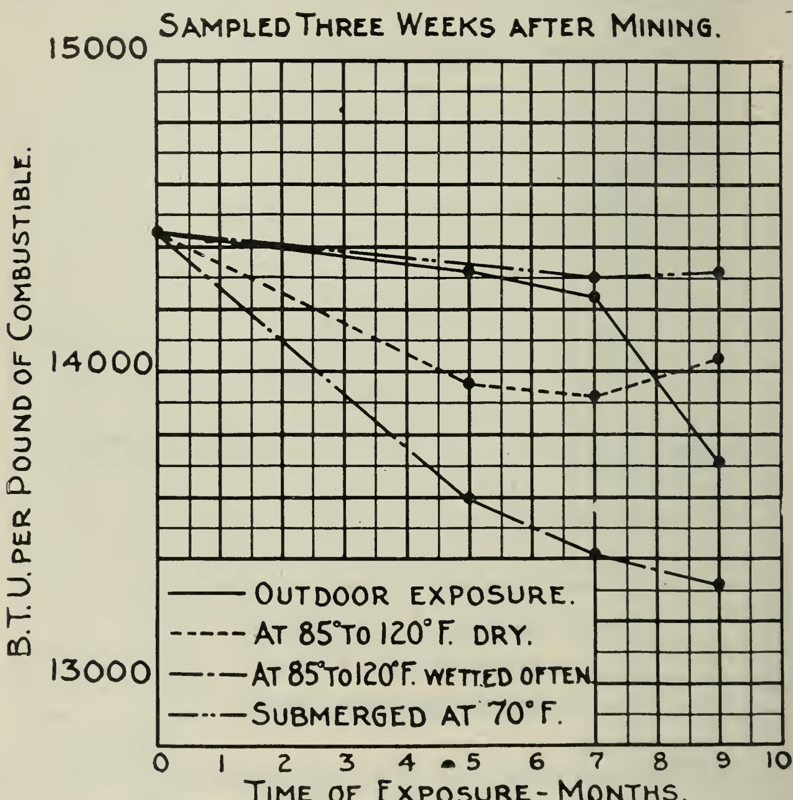



FIG. 17. Perry county "No. 7" coal; nut and slack.

A further test was also afforded in the case of a half car of coal which had been exposed to weathering conditions for a little over twelve months, Nos. 8 and 9. Another sample, No. 7, represents a barrel of this coal which had been stored by submerging at the outset of the test—presumably about one week after mining—and, which, on the theory that values in that condition had remained practically unchanged, is made use of as the basis of comparison for these Westville samples. The main lot of fifteen tons was piled on the ground in a rather low rounded heap without cover, and thus exposed from October, 1906, to December, 1907. A sample was taken from over

the surface and another from the entire mass by throwing out every twentieth shovelful in the process of moving the pile. The purpose of the test was to determine the difference in loss between the exposed surface coal and that of the entire lot. While a slightly greater loss is shown in the surface layer, No. 8, it is so easily within the variations of experimental error, that so far as this rather limited test goes, there is not indicated an appreciably greater loss at the surface than within the heap. The results on this fifteen-ton lot are referred for comparison to the submerged sample, as being most nearly of the value corresponding to the freshly mined coal. The last value on a four-weeks-old sample, No. 10, is added as showing the drop in value for that length of time.

The possibility of a large drop in values during the first few days after removal from the seam was not suspected soon enough to be taken into the account for the main series of tests as set forth in the charts. Some of these weathering tests, therefore, show a smaller decrease in calorific value than actually occurs, as the first analyses represent the coal several days after mining, instead of the day it was mined.

| Test No. | Material. | B. t. u. per pound referred to Ash, Water and Sulphur Free. | Drop in Heat Units compared with Initial Values. |
|---|---|---|---|
| | Belleville field, Illinois ("No. 6" Coal)— | | |
| 1 | Fresh face sample | 14785 | |
| 2 | Pillar coal, 22 years exposure | 14372 | 413 |
| | Saline-Gallatin field, Illinois ("No. 5" Coal)— | | |
| 3 | Fresh face sample | 15188 | |
| 4 | Pillar coal, 27 years exposure | 14755 | 434 |
| | Danville field, Illinois ("No. 6" Coal)— | | |
| 5 | 1¼ Screenings. 1 week from mine | 14627 | |
| 6 | 3 Nut. 1 week from mine | 14586 | |
| 7 | 1¾ Screenings, submerged 1 week after mining, and stored 1 year | 14588 | |
| 8 | From surface of 15-ton pile, 1 year exposure | 14241 | 347 |
| 9 | From throughout 15-ton pile, 1 year exposure | 14264 | 324 |
| 10 | Four weeks after mining | 14410 | 178 |

As bearing still further upon this matter, opportunity has also been afforded for noting the drop in values during the time of shipment from various mines to the University. Shipments of 1¼″ screenings and 3″ nut were made from three different mines and the coal sampled as it was loaded and resampled approximately one week later as it was unloaded.

The results are tabulated below. Attention is called to the fact that here is uniformly a drop in calorific values, which is slightly greater in the larger size.

*Loss in Calorific Value during Transit.*

| Test No. | Locality. | Size of coal. | When sampled. | B. t. u. of ash, water and sulphur; free coal. | B.t.u. lost. |
|---|---|---|---|---|---|
| 1 | Danville field | 1¼″ screenings | Same day as mined | 14684 | |
| | ..do | ..do | 7 days after mining | 14627 | 57 |
| 2 | Springfield area | 1¼″ screenings | Same day as mined | 14478 | |
| | ..do | ..do | 4 days after mining | 14351 | 127 |
| 3 | Williamson Co | 1¾″ screenings | Same day as mined | 14658 | |
| | ..do | ..do | 6 days after mining | 14553 | 105 |
| 4 | Danville field | 3″ nut | Same day as mined | 14768 | |
| | ..do | ..do | 7 days after mining | 14596 | 182 |
| 5 | Springfield area | 3″ nut | Same day as mined | 14655 | |
| | ..do | ..do | 4 days after mining | 14461 | 194 |
| 6 | Williamson Co | 3″ nut | Same day as mined | 14751 | |
| | ..do | ..do | 6 days after mining | 14682 | 69 |

All of these samples were analyzed within a few days of the sampling, but as both sets were analyzed at the same time, and there was a possible deterioration of the mine samples while in the sealed laboratory containers, as shown elsewhere in this bulletin, the drop in value may have been even greater than is indicated in the table.

## SUMMARY.

(*a*) Submberged coal does not lose appreciably in heat value.

(*b*) Outdoor exposure results in a loss of heating value, varying from 2 to 8 per cent.

(*c*) Dry storage has no advantage over storage in the open except with high sulphur coals, where the high disintegrating effect of sulphur in the process of oxidation facilitates the escape of hydrocarbons or the oxidation of the same.

(*d*) In most cases the losses in storage appear to be practically complete at the end of five months. From the seventh to the ninth month the loss is inappreciable.

(*e*) The results obtained in small samples are to be considered as an index of the changes affecting large masses in kind rather than in degree, but, since the losses here shown are not beyond what seems to conform in a general way to the experiences of users of coal from large storage heaps, it may be not without value as an indication of weathering effects in actual practice.

Further studies are in progress having reference to actual storage conditions.

# Ash in Coal and its Influence on the Value of Fuel.

(BY A. BEMENT.)

Strictly speaking, ash is an impurity in, or combined with coal and in no proper sense a part of it. It is, rather, incombustible mineral matter associated with the fuel and remains as a residue after combustion: Under no circumstances is it in any way beneficial; on the contrary, its presence is decidedly harmful. In fact, the ash affects the value of coal in larger measure than any other feature of the fuel composition.

From a chemical standpoint ash is of more complicated composition than coal proper, as the following list of elements found in it tend to show:

| Principal Elements of the Ash. | Elements of the Coal. |
|---|---|
| Silicon.<br>Calcium.<br>Magnesium.<br>Iron.<br>Aluminum.<br>Sulphur.<br>Oxygen. | Carbon.<br>Hydrogen.<br>Sulphur.<br>Oxygen.<br>Nitrogen. |

In addition to these principal elements, there are others present in much less quanity. These, in various combinations together with alkalis, form compounds which are more or less fusible at temperatures of the fire, and this ready fusibility allows the production of clinkers. In a general way the clinker making compounds may be considered to be glass, fire clay and iron compounds. The clinkers form large masses and are an obstruction which prevents a free entrance of air to the fire. The iron comes from within the seam and is mainly in the form of iron pyrites. The melting of the iron, if present in sufficient amount, produces a serious clinker. The fire clay is more particularly from the strata underlying the coal and its fusion also forms large clinkers.

It is thought by some firemen that coal will melt and "run," and often this belief is strengthened by the ready formation of a very fusible and black clinker, which is considered to be melted coal. As a matter of fact, dry coal does not melt; it is the ash associated with it that fuses, and if ash were absent no fusion would ensue. The fusing of coking coal is an entirely different process and does not result in the formation of clinker. It is also sometimes believed that coal may

be of such character as to leave a larger residue of ash or clinker in some cases than in others, and that ash may be derived from the coal; or, in other words, that some portion of the coal may turn to ash. This is also an error, because all of the residue except pieces of unburned coal comes from the ash which is in and associated with coal. In this connection it is desirable to define the meaning of the word coal with more exactness than usual, in order to avoid confusion. Coal is, therefore, here used to mean the heat producing elements which, together with the ash and moisture, make the fuel composition.

A distinction may be made between the ash in the fuel as follows:

1. Ash in the clean coal itself.
2. Ash in the entire seam of coal distinct from that in the clean coal.
3. Ash associated with the coal which becomes mixed in during mining, but is not derived fom the seam.

It is not only desirable, but necessary, to recognize these distinctions for a proper understanding of the matter. For example, if a clean lump of coal is selected and burned in the laboratory, it will be found that residue remains, notwithstanding the fact that the lump of coal gives no indication by its appearance of the presence of any ash. Thus, ash is present in the clean coal itself, and from the strict chemical standpoint this may be considered the true ash, any additional foreign matter being really dirt mixed with the coal, rather than ash in coal.

The ash present in the entire coal seam as it exists in the ground consists of that which is invisible and intimately associated with the clean coal itself and also pyrites occurring in the form of bands, streaks and wedges, slate bands, etc. If the entire seam be mined and shipped as mine run coal, even without any admixture of roof or bottom clays, it will contain two kinds of ash; that present in the coal seam itself and that which is more or less disassociated from but mixed with the coal, although coming entirely from the seam. There is also, however, in all commercial coal more or less dirt from sources outside of the coal seam; such as from the strata overlying the bed and the floor of the mine. Both may, and do, contribute more or less dirt to the fuel. Fuel coal, therefore, as mined may have ash present in the following degrees, depending upon the amount of preparation which the fuel may receive:

1. a In the clean coal.

2. a In the clean coal.
   b The distinct impurities which come from the seam.

3. a In the clean coal.
   b Impurities from the seam.
   c Dirt from outside of the seam.

A distinction is also recognizable in ash in clean coal, as sometimes parts of the seam may have strata in which the ash is quite high, yet the clean black lump of coal may not give any indication of its presence. This is referred to as bone or bone coal, a term used to distinguish between it and coal containing a normal amount of ash. The vegetable matter from which the coal was formed contained mineral matter in the makeup of its last plant structure. That this must be

true is evident from the fact that a residue ash remains when wood is burned. Therefore, the ideal clean coal contains an amount of ash depending on the quantity of mineral matter that was present in the vegetable matter which formed it. But a bench or division of a seam may contain but little ash. These benches or divisions are sometimes but a few inches or fractions of an inch thick, and it is not reasonable to assume that the vegetable forming them contained such a large quantity of mineral matter. It is more probable that when the strata of bone coal was originally deposited, a greater or less quantity of mud was present and accumulated with the vegetable matter. Such bone coal benches may range through various gradations from ideal clean coal to a bituminous shale. Thus, a distinction could be made between the sorts of ash in what has been considered as clean coal in the foregoing by differentiation between the ash due to mineral matter in the plant structure and to mud buried with the vegetable matter. It is hardly necessary, however, to apply such a distinction to Illinois coal seams, because strata of bone are neither sufficiently numerous or of such serious character as to require it being made.

Bituminous coal of the Appalachian field is lower in ash than that of Illinois, for which there may be two explanations. The mineral matter in the plant structure forming the eastern field may have been less than in Illinois. Or, in the formation of the beds of the basin of which Illinois is a part there may have been a considerable quantity of mud and slime deposited with the vegetable matter as characteristic of the field in general. Adopting the latter view, it may be that Illinois coal is all of a mild bone variety.

The character and value of fuel is to a large extent dependent on the preparation it receives, and for fuel to be of good quality requires that it be well prepared; and this necessitates, as far as ash is concerned, that the pyrites, slate bands, dirt, etc., as well as any bone coal, be removed from the fuel. This is usually done before it is sent out of the mine. There is very little attention paid to preparation of the larger sizes of fuel in Illinois after its removal from the mine, with the exception of some slate, rock and pyrites which are thrown out from lump, mine run and egg coal by men stationed for that purpose on the railway cars during loading. Smaller sizes are frequently washed whereby it is possible to reduce the ash to a minimum, so that it is no greater in amount than due to that in the clean coal itself. In addition to washing, the fuel is usually graded at the washers into suitable and uniform sizes known as No. 1 to 5, inclusive.

The accompanying diagram shows very strikingly the harmful effect of the presence of ash on the value of fuel. This matter has been treated in a paper by Mr. W. L. Abbott* entitled "Some Characteristics of Coal as Affecting Performance with Steam Boilers," and it is the result of a series of his experiments that is shown in this diagram. It is seen that the efficiency and capacity of the boiler dropped to zero when the ash in the dry fuel became as great as 40 per cent, although

*Journal of the Western Society of Engineers, vol. 11, p. 529.

the location of the points shows that the efficiency is less affected than capacity below 35 per cent of ash. From this point the drop is very rapid, while the influence on capacity is more gradual.

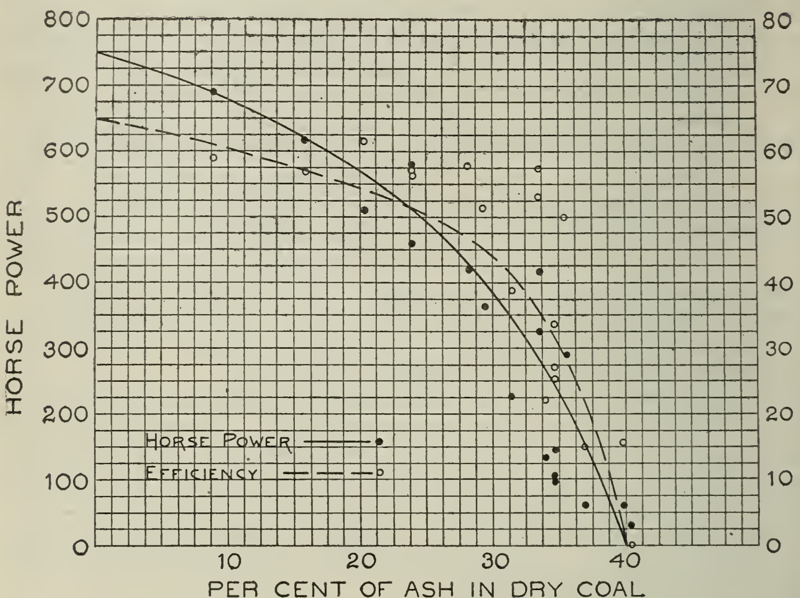



FIG. 18. Ratio of Horse Power and Efficiency to per cent of Ash in Steam Generation.

Ash is the feature having the greatest influence on the value of fuel coal. Its presence like that of the moisture acts to exclude a certain portion of the pure coal which would otherwise be present, and in this way it may be considered as a dilution similar to moisture. While, however, the moisture evaporates and passes away, ash remains as a residue to choke and obstruct the fire, entailing much labor and inconvenience in its removal.

In mine run coal or screenings moisture could not well average more than 15 per cent. The presence of this amount in a fire under a boiler would not result in the loss of more than 2 per cent of the heat at the most, while the maximum amount of ash which might be present could cause a loss of 100 per cent; or, in other words, render the fuel worthless, if its use in that condition be attempted.

The coal seams of Illinois contain approximately 9 to 10.5 per cent ash; the amount being quite uniform for each of the seams mainly mined. This ash includes not only that in the clean coal, but also the distinct impurities in the form of bands, pyrites, etc., some of which are supposed to be removed in the process of mining. Thus, it might be expected that mine run coal from such a seam would contain less than 10 per cent of ash. As a matter of fact, under present conditions it is considerably higher, as shown in table No. 1, which gives approxi-

mate ash values for various grades of fuel under present mining conditions. This amount of ash in fuel coal is not only much higher than it should be, but in Illinois is rather on the increase than decrease. Changing conditions under which miners work are responsible for this, and rather to their independence than neglect on the part of the producer of the coal is this large amount of dirt shipped. If coal were carefully prepared by the men who mine and load it ready for transportation from their place in the mine, it would contain approximately the amount of ash in table No. 2.

One of the principal causes of dirty coal is the use of excessive charges of powder in blasting out the coal where it is shot from the solid face, instead of being undercut. The effect of this practice, besides the production of an excessive quantity of small coal which must be sold as screenings, is to damage the roof so that there are falls of dirt into the mined coal. In addition, the force of the blast projects the coal a great distance out into the room, so that it is spread over the floor in a thin layer, and in shoveling it up dirt in larger or smaller quantities is taken from the fire clay bottom, which is more or less soft. This, and the failure to remove dirt and impurities derived from the seam when the coal is loaded by the miner, are the leading causes of unclean coal.

### TABLE NO. 1.

*Ash in Dry Coal Under Present Conditions of Production.*

| | PER CENT OF ASH IN DRY COAL. | | |
|---|---|---|---|
| | Average maximum. | Average minimum. | Average. |
| Lump and Egg | 16.0 | 11.5 | 13.5 |
| Mine Run | 19.0 | 12.0 | 15.7 |
| Raw Nut | 16.0 | 12.0 | 13.0 |
| Raw Screenings | 19.0 | 15.0 | 17.5 |
| Washed Screenings | 13.0 | 9.0 | 12.0 |
| Washed Sizes:— | | | |
| No. 1 | 11.0 | 9.7 | 10.0 |
| No. 2 | 9.7 | 8.6 | 9.0 |
| No. 3 | 9.5 | 8.5 | 8.8 |
| No. 4 | 10.8 | 9.7 | 10.2 |
| No. 5 | 13.8 | 12.0 | 12.4 |

TABLE NO. 2.

*Ash in Dry Coal for Properly Mined and Prepared Fuel.*

| | PER CENT OF ASH IN DRY COAL. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Average. |
| Lump and Egg | 11.5 | 9.5 | 10.5 |
| Mine Run | 13.0 | 11.0 | 12.0 |
| Raw Nut | 12.0 | 10.0 | 11.0 |
| Raw Screenings | 15.0 | 12.0 | 13.0 |

To avoid misunderstanding, the writer wishes to say that washed coal, as furnished in Illinois, is as low in ash as the so-called smokeless or semi-bituminous coal shipped into Chicago under the name of Pocahontas, etc., and will add that ash values in coals in general have been largely underestimated. It is well to direct attention to this fact, because readers of the above might conclude that ash in coal outside of Illinois is relatively lower than that of this State. One of the difficulties has been that formerly very little authentic data has been available, and for this reason it is felt that the statement of values presented in these two tables should be helpful.

# Coal Investigations in the Saline-Gallatin Field, Illinois, and the Adjoining Area.*

(By Frank W. DeWolf.)

## Introduction.

The area here described is near the southwest edge of the Eastern Interior coal field, lying mostly in Illinois, but extending also into Indiana and Kentucky. Its boundaries are slightly beyond those of the Eldorado and New Haven quadrangles, and it measures 30½ miles from east to west and 18½ miles from north to south, thus including approximately 550 square miles. Parts of four counties in Illinois—Saline, Gallatin, White and Hamilton—are comprised within the area.

Coal production in this region is increasing so rapidly that geologic work carried on here assumes an important economic aspect. The rapid development of this part of the coal basin is due to the excellent quality of the fuel, its extensive distribution and favorable mining conditions. The production to date has been entirely in the Illinois portion of the area and until the last year only in Gallatin and Saline counties. White county also is now producing. In 1906 the area included in this report produced 314,927 tons, a gain of 115 per cent over 1905.† Coal mining in the Eldorado quadrangle is facilitated by the presence of several railroads; the New Haven quadrangle has none. The whole area, however, has so little relief that it can be easily reached by railroads where desired.

This preliminary statement of geologic field work performed during three autumn months of 1906 is the first published report for this area since 1875,‡ though adjoining areas in Indiana§ and Kentucky‖ have received later attention. The two quadrangles here described are the first of a series extending across the southern Illinois coal field, the mapping of which will be completed in the near future. The topographic and geologic work is being executed in coöperation by the Illinois Geological Survey and the United States Geological Survey. Information in regard to additional quadrangles on the west side will also be included in the final report.

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*Reprinted by permission from Bull. 316 U. S. Geological Survey.
†Mineral Resources U. S. Geol Survey, 1906.
‡Geol. Survey Illinois, vol. 6, 1875.
§Rept. Indiana Dept. Geol. and Natural Resources, 1899, pp. 1399, et seq.
‖Repts. Inspector of Mines of Kentucky, 1893, etc.

The writer is indebted to Stuart Weller and David White for their assistance in correlating the rocks of the region and to George H. Ashley for suggestions in the office. Such value as this report possesses is due largely to the kind coöperation of those coal companies which have placed drill records and other data in the hands of the survey. To many well drillers and other persons thanks are cordially given for numerous services.

## Surface Relief and Drainage.

Mining conditions in this field are rendered favorable on the whole by the moderate surface relief. Though the altitudes vary from 340 to 600 feet above sea level, most of the area lies between 365 and 420 feet. The drainage is tributary to Ohio river directly or through the Wabash, Little Wabash and Saline rivers and their branches. It is deficient in a large area, especially along the Wabash, but considerable reclamation is promised by systematic ditching now in progress.

The topography is of two types—uplands and bottoms. Prominent hills of the New Haven quadrangle are indicated on Pl. 8. Bottom lands constitute about two-thirds of the area of the New Haven quadrangle and about one-third of the Eldorado.

The detailed topographic character of the area and the distribution of timber, houses, roads and land lines are indicated on the colored contour maps of the Eldorado and New Haven quadrangle.* Pl. 9 shows relief and altitude above sea level by contour lines, each of which passes through points of equal altitude on the land, one being drawn for every twenty feet of increase in elevation.

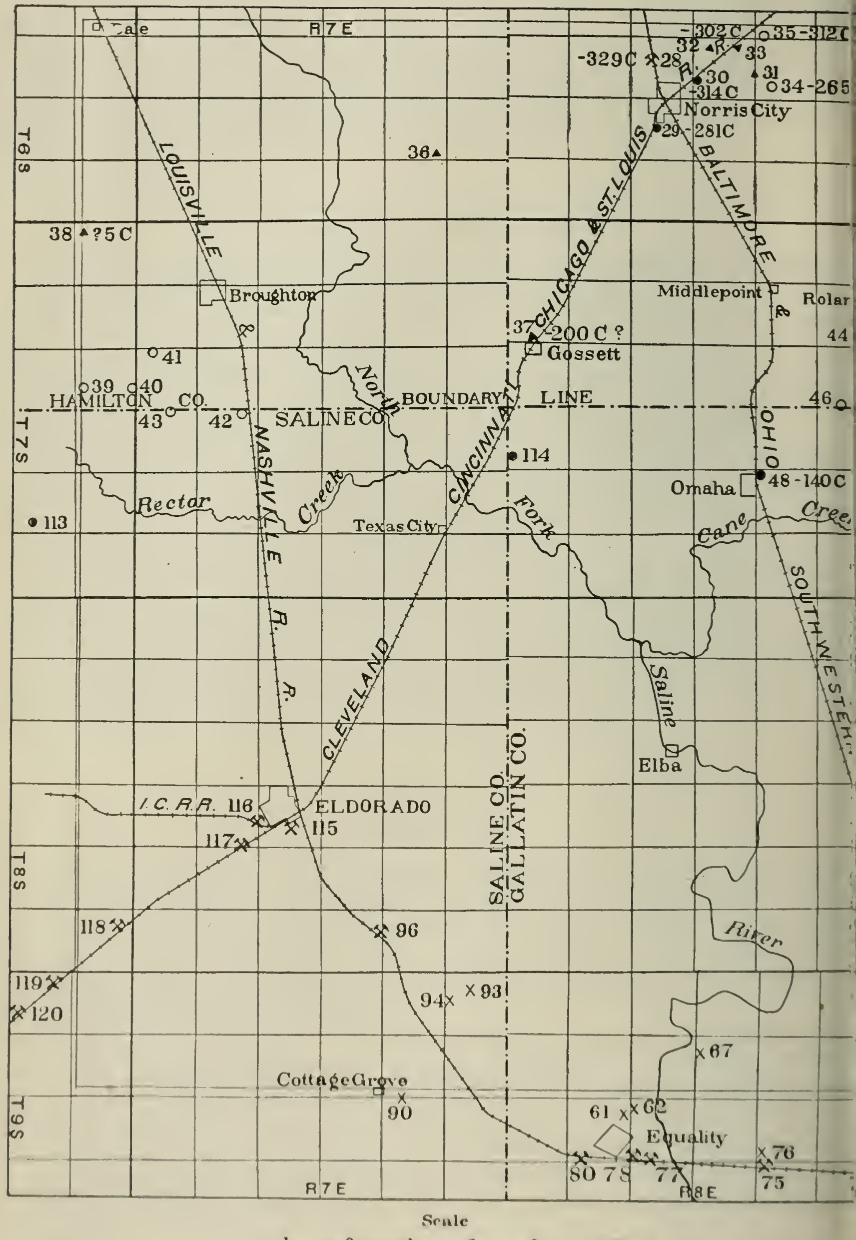
## Geology.

### Introduction.

The economic value of the geologic examination of the various coals of this region lies in determining for each its vertical position, horizontal extent, thickness, quality, structure and correlation with beds in other areas. Since the study of the region has not been fully completed, some of the field observations may be subject to a different interpretation in the final report.

Field work is difficult here because of the presence of glacial and fluviatile deposits which very largely conceal the underlying rocks. The most valuable data were obtained from numerous records of coal borings and a few deeper holes bored for oil. A little information was also derived from water wells. The best exposures of value are those occurring beyond the drift border in that region immediately to the south of this area along Saline river and in the neighboring part of Kentucky.

*These maps may be obtained for 5 cents each by addressing The Director, U. S. Geological Survey, Washington, D. C.



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CHICAGO & ST. LOUIS
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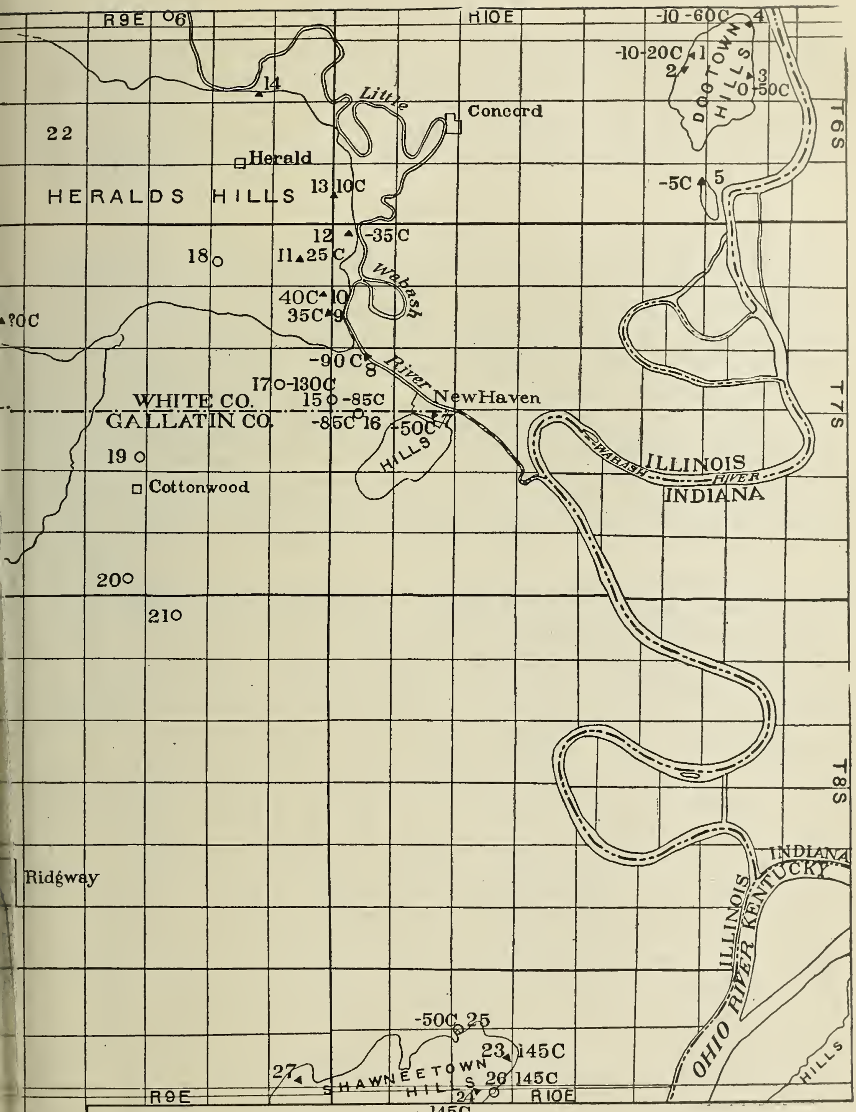


## Legend

- ⚒ Commercial mines.
- X Local mines.
- ▲ Rock outcrop.
- ● Coal test boring.
- o Well.
- **52C** Calculated altitude of coal No. 5 above sea level.
- **67** Datum locality referred to in test or mine table.

## STRATIGRAPHY.

### GENERAL STATEMENT.

The rocks of this area consist of a varying thickness of fluvial and glacial deposits, overlying alternating shales and sandstones with relatively thin, more or less lenticular beds of limestone, coal and fire clay. They have been explored to a depth of about 1,500 feet. The hard rocks belong to the Pennsylvanian series of the Carboniferous system.

### CORRELATION.

Division of the Pennsylvanian beds of the Kentucky-Illinois area in earlier reports into the "Upper" or "Barren Measures" and the "Lower" or "Productive Measures" was made partly for convenience and partly to conform with earlier subdivisions of the Carboniferous rocks in Pennsylvania. D. D. Owen* used as a horizon for this division the Anvil Rock sandstone. In later reports for Illinois A. H. Worthen† used, instead, the Carlinville limestone, a bed higher stratigraphically, thought to be identical with the Carthage limestone of Kentucky. It may be questioned whether either of these two horizons or any other has sufficient persistence and prominence to be employed for the division throughout any large part of the Eastern Interior coal basin.

For further convenience in description and correlation the old surveys of Kentucky and Illinois numbered the coal beds upward from the bottom. In the "Lower Measures" the old Kentucky section, however, shows twelve numbered coals, with a few additional beds either designated by letters or not named; while the old Illinois section distinguishes nine numbered coals, and recognizes one of minor thickness to which no number has been applied. The total number of Pennsylvanian coals in the old Illinois section is sixteen. The two stratigraphic columns compiled by the old surveys disagree in the lower portions, and likewise in the upper portions, since Illinois reports place the Carthage limestone not more than 184 feet above coal No. 7,† whereas Kentucky reports describe it as occurring 450 feet above the corresponding bed.‡ In the middle portion of the column, however, the coals numbered by Worthen from 8 to 2 seem to be identical with the similar series numbered from 12 to 5 by Owen.§ No single columnar section can safely be considered representative of conditions over a wide area, since the character of the rocks varies greatly within short distances. As the sections in Pl. 10 indicate persistence of certain beds, however, there is reason to hope that study of drill records and field evidence will result in a correct correlation of the various horizons. The present use of numbers in the Illinois fields probably does not indicate the true correlation of the coals, though

*Kentucky Geol. Survey, vol. 1, 1856, pp. 30-45.
†Geol. Survey Illinois, vol. 6, 1875, p. 3.
‡Geol. Survey Kentucky, vol. 3, 1857, p. 20.
§See correlation sheet by C. J. Norwood, in Rept. Inspector of Mines in Kentucky, 1893, p. 96.

locally over considerable areas the designations are doubtless consistent. It seems advisable in this report to use the numbers so widely accepted in this region, but with the understanding that they are of local significance only and do not imply correlation with beds bearing the same numbers in other areas.

GENERAL DESCRIPTION OF STRATIGRAPHIC COLUMN.

The approximate columnar sections given in Pl. 10, compiled from outcrops and borings, indicate the character of the rocks in several parts of the area and show the apparent persistence of certain beds and the local, lenslike character of others. The variations exhibited, however, are due in part to scant and imperfect data. Of the localities referred to in this paper, Nos. 49-112 are shown on Pl. 9 and the others on Pl. 8.

The persistence of the coals from No. 8 to No. 5, inclusive, is notable in the columnar sections. Other beds of special importance stratigraphically are certain limestones. One occurs in section 1, 265 feet above coal No. 7, and is also shown in section 2. Another is indicated in section 3, 190 feet above No. 7, and a third occurs in the same section 45 feet above No. 7. The first of these is tentatively regarded as the Carthage limestone, which is especially important here. It takes its name from a former settlement three-fourths of a mile west of Uniontown, Ky., where the rock is exposed along Ohio river. When fresh, it is hard and blue gray in color, outcrops in vertically-jointed cliffs, and shows a tendency to split into slabs. When weathered, the rock is usually buff or reddish brown. On its surface and through its interior occur abundant brachipods, crinoid stems and other fossils. Because of the persistence of these lithologic characters and the similarity of fossil content, limestones at several localities within the area have with some hesitancy been identified with the Carthage.

The distance from this bed to the identifiable coals of the section has considerable economic interest and is a matter of disagreement in the old State reports, as already indicated. It is probable that neither of the old estimates is clearly applicable to this region, although the evidence here presented is not altogether conclusive.

At New Haven a churn-drill well, which commenced on a level with a limestone, probably Carthage, outcropping at loc. 7, reached a thin coal at 260 feet and stopped in a limestone 10 feet lower. No coal referable to No. 7 was passed, though the bottom limestone may be the roof of that bed. At Round Pond (loc. 26) a well commencing 160 feet below the outcrop of a limestone, presumably Carthage, reached a two-foot coal at a distance of 268 feet below that bed, but passed none with the usual characteristics of coal No. 7. In borings near Junction, which strike the first hard rocks 230 feet above coal No. 7, no limestone comparable to the Carthage is reported. These records show either that the interval between the Carthage and the No. 7 coal at these localities exceeds 270 feet, or that there is a lack of development or absence at the first two places of the No. 7 coal and at the last of the Carthage limestone.

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A core drill at Norris City (loc. 30) reached a five-foot limestone 265 feet above coal No. 7. As this limestone is almost identical in character with the Carthage, and carries the same fossils, it may be regarded as that bed, especially because the associated strata are similar to those observed with the so-called Carthage, as indicated in section 2 (Pl. 10). The interval between the Carthage and No. 7 coal at Norris City seems, therefore, to be 265 feet.

This limestone does not occur around Eldorado. At loc. 102 a thin dark blue limestone occurs about 225 feet above the horizon of the No. 7 coal, as determined at loc. 103, but at locs. 104, 105, 106, 107 and 107½ no limestone is reported at this horizon. One occurs, however, 190 to 210 feet above No. 7 in all the borings in that vicinity which reach its horizon. Its persistence and uniform thickness of about five feet suggest that this bed may possibly be the Carthage, though it is separated from the No. 7 coal by an interval 55 to 75 feet less than at Norris City, Equality, New Haven and Round Pond. Such a change in interval, although improbable, is perhaps further indicated by the imperfect record at Omaha (loc. 48), which reports a hard limestone at 180 feet and coal, comparable to No. 7, 225 feet lower. It seems more likely that the Carthage limestone is lenticular and that it dies out between Norris City and Eldorado or is represented by the thin limestone reported at loc. 102 and others near by. If the identifications as Carthage of various limestone beds in this region is correct, its outcrop, representing the boundary between the upper and lower "Coal Measures," would be indicated roughly, beginning near Dogtown, by a line connecting locs. 4, 5, 7, 44, 49, 97, 101 and 103 with an outlyer in the Shawneetown Hills and the area westward to Junction. Future work must demonstrate whether the Carthage limestone can be identified and used as a key rock over this coal field.

Another limestone, as already noted, occurs rather persistently 45 feet above the No. 7 coal. It is generally encountered in borings in the southwest corner of the area and outcrops one and one-half miles west of Cottage Grove at loc. 88.

## Structure.

### General Statement.

Although the coals and associated strata of this region are nearly parallel and horizontal, the distances between the strata change from place to place and the beds slope or dip in varying directions and amounts. The determination of the attitude of the coals is important for the reason that economical mining must take advantage of natural slopes for haulage, drainage and ventilation.

The structure bears an intimate relation to an east-west displacement, just south of the area mapped, which marks the north edge of Gold Hill Range. The amount of this disturbance, which has caused a relative sinking of the strata to the north, is roughly indicated by data obtained at Equality, Cottage Grove and in the hills to the south. The lower slope of the range reveals limestones of Mississippian

age; the capping is the Caseyville conglomerate. In Prospect Hill this conglomerate has an altitude of about 900 feet, and the altitude of coal No. 5 at this point, if uneroded, would be over 1,425 feet. The same coal three and one-half miles farther north, at loc. 84, is nearly 1,300 feet lower, or at an altitude of 145 feet. There is no evidence that this change in level is due to dip, for at both localities the rocks appear to dip southward.

The dips of the coals are predominantly northward, toward the center of the Eastern Interior basin. There are, however, numerous local exceptions. The amount of dip also varies greatly; it exceeds 100 feet to the mile in some localities, but probably averages only half that amount and locally is negligible. There is some evidence of conditions similar to those in the faulted area on the south. Thus at Eldorado, in O'Gara mine No. 8, a six-foot dike of igneous rock cuts vertically through coal No. 5 and produces a narrow zone of "natural coke." The rock resembles and probably is related to dikes of the Illinois-Kentucky fluorspar district. Elsewhere there are certain abrupt changes in level of the beds, possibly due to faulting, as between Equality and Junction. These conditions are described on page 217. The possible occurrence of such structural changes within the untested areas treated in this report is a source of uncertainty in the determination of the horizontal distribution of the coals.

### METHOD OF SHOWING STRUCTURE.

The dips are indicated by a comparison of the figures placed on Pl. 8, which show, at various datum points, the measured or calculated altitude of coal No. 5. Additional evidence in the southern portion of the Eldorado quadrangle is shown on Pl. 9. The structure contours of this map were drawn in the following manner: The depth to coal No. 5 was either determined from records of test holes and shafts or calculated from the presence in shallow wells or at surface outcrops of other higher strata which could be identified. This figure at each datum point was subtracted from the altitude of the ground in order to obtain the altitude of the coal. Where the coal lies at different altitudes at adjoining points the dip between these was regarded as uniform and points of equal altitude were connected by a contour line. Thus, between every two contours there is indicated a dip of 25 feet, except in the southeast corner, where every other line is omitted and the dip is 50 feet between contours. The resultant map may be slightly inaccurate. As the surface elevations were determined by hand level or barometer from bench marks, there are probably small errors. Furthermore, it is possible that in a few places where the depth of the coal was calculated from overlying beds the interval assumed was slightly incorrect. The most important source of error is the assumption that between datum points dips are uniform. It is still reasonably certain that in Saline county the error along any contour line is less than 25 feet, but in Gallatin county, because of lack of data, it may be more.

The dips of the area are readily determined by reference to this map, but attention should be called to the possibility of faulting as an explanation of abrupt changes in altitudes in certain localities. Such an explanation is suggested for changes in elevation of the Carthage limestone in the Shawneetown hills, at locs. 23 and 25.

At Cottage Grove either an anticlinal fold trending east and west or a fault with the downthrow on the south is indicated, for between locs. 84 and 89 there is a change in level of 85 feet in three-fourths of a mile. An abrupt descent of 100 feet also occurs from locs. 93 and 94 to loc. 95, though the distance but slightly exceeds half a mile. Similarly, a descent of about 115 feet occurs from loc. 119 to loc. 120, three-fourths of a mile apart. Underground workings have not yet shown whether this is due to dip or to a fault.

The most interesting locality from this standpoint lies in the southeast corner of the area, between Junction and locs. 75 and 76, where the contours show an apparent dip of 400 feet in one and three-fourths miles. There is an additional source of possible error here, since the correlations may be incorrect. Probably the test holes in this vicinity, except at locs. 73 and 72, stopped in coal No. 7. The hole at loc. 73 stopped just before reaching it, and that at loc. 72 went through to No. 5. If, however, this interpretation of the records is incorrect and all these test borings reached No. 5, then there is an additional descent of 120 feet between the points mentioned and loc. 73. A considerable proportion of this descent may be due to a fault along a north-south line.

Some such condition is indicated also between locs. 70 and 71, where the levels change 180 feet in half a mile. The information at loc. 70, however, was obtained from a churn-drill boring and may be incorrect.

## Descriptions of Datum Localities.

The following notes record observations at the localities shown by numbers on the accompanying maps, except those made at coal mines, which are grouped in a later table. Locs. 1 to 48, 113, and 114 are shown on Pl. 8, the others on Pl. 9, and where possible the calculated altitude of coal No. 5 is shown.

*Locs. 1-18*—At these points occurs either the Carthage limestone, an upper bed lying stratigraphically about 50 feet higher, or other closely associated strata. Thin coals usually underlie the limestones. In this region coal No. 7 may be looked for about 275 feet below the Carthage limestone, and coal No. 5 about 120 feet lower. They should occur 50 feet farther below the upper limestone.

Locs. 1-4: The public roads near Dogtown show outcrops of an 18-inch limestone which is underlain by a thin coal at locs. 1 and 2 and which resembles the Carthage bed in fossil content, but corresponds to the higher limestone in thickness. It is from 385 to 395 feet in altitude.

Loc. 5: At the base of the hill occurs a thin coal overlain by a limestone 6 feet thick, which is probably Carthage.

Loc. 6: A 3-foot limestone struck in the well of David Hayes probably occurs stratigraphically considerably above the Carthage.

Loc. 7: At New Haven an exposure occurs in the river bank as follows:

*Section at New Haven.*

| | Feet. | Inches. |
|---|---|---|
| Limestone (Carthage), blue-gray, hard, brittle, fossiliferous...... | 5 | |
| Shale, black.......... | 3 | |
| Coal .......... | | 2 |
| Fire clay.......... | 3 | |
| Sandstone and shaly sandstone, soft, fine grained.......... | 6 | |
| Shale, sandy.......... | 5½ | |
| Sandstone, fine, soft, thin bedded, gray-brown.......... | 3 | |
| Low water, Little Wabash river. | | |

Loc. 8: Near the mouth of Rocky Branch a limestone bed 18 inches thick forms a riffle across the Little Wabash. It carries a somewhat different fauna from the Carthage, which it probably overlies by 50 feet. Above it occurs 6 feet of blue-gray shale bearing iron nodules and below it streaks of coal, embedded in 1 foot of bituminous shale and underlain by blue clay shale.

Locs. 9-18: The same coal and limestone or beds near this horizon are exposed in ravines to the north, accompanied by the beds shown in the columnar sections. A summary follows.

*Summary of observations at locs. 9-18.*

| Loc. No. | Name. | Kind of rock. | Coal. | | | Remarks. |
|---|---|---|---|---|---|---|
| | | | Thickness. | Depth. | Altitude. | |
| | | | *Inches.* | *Feet.* | *Feet.* | |
| 9 | .......... | Limestone, coal...... | + | 0 | 410 | .......... |
| 10 | Owen Wilborn.......... | ..do..........do...... | + | 0 | 415 | .......... |
| 11 | J. F. Medlin.......... | Sandstone, coal....... | 18 | 0 | 430 | Old mine..... |
| 12 | .......... | Limestone, coal...... | + | 0 | 370 | .......... |
| 13 | .......... | Coal.......... | + | 0 | 415 | Old mine..... |
| 14 | "Devil's Biscuit"..... | Sandstone *.......... | .......... | .......... | .......... | .......... |
| 15 | Mrs. Rhoda Grant.... | Limestone, coal...... | + | 60 | 360 | .......... |
| 16 | John Sturm.......... | ..do..........do...... | + | 60 | 360 | .......... |
| 17 | Alex. Questell........ | Coal.......... | + | 125 | 315 | .......... |
| 18 | Isaac Bayley.......... | ..do.......... | + | 200+ | 330— | .......... |

* Thickness of sandstone 20 feet; altitude 380 feet.

*Locs. 19-22*—There is some doubt in regard to the stratigraphy of the thin coals and hard rock, presumably limestone, which occur in wells near Cottonwood, and of the sandstones and underlying shale exposed along the hill roads to the north, as at Iron.

*Locs. 23-27*—In the region of Round Pond three occurrences of the Carthage limestone furnish a basis for calculating the altitudes of workable coals.

*Section at Round Pond.*

| | Feet. |
|---|---|
| Limestone, Carthage, altitude 540 feet | 5 |
| Concealed | 2 |
| Coal, bloom | + |
| Concealed | 24 |
| Sandstone, hard, massive, gray | 30 |
| Concealed | 35 |
| Shale, argillaceous and sandy, blue-gray | 33 |
| Concealed | 5 |
| Shale, brown | 5 |
| Shale, black, and coal bloom | 2 |
| Shale, brown, sandy | 20 |
| Concealed to Round Pond | 40 |

Loc. 24: The limestone occurs also at the same altitude near the top of the hill at the road forks.

Loc. 25: A limestone 35 feet below the surface in the well of William Satterly overlies a 2-foot coal and appears on the evidence of lithologic character and fossils to be the Carthage. Its altitude, 195 feet lower than at loc. 23, is probably due to a fault.

Loc. 26: A churn-drill well on the R. L. Millspaugh farm, starting 160 feet below the Carthage limestone, passes through 37 feet of clay and gravel, 71 feet of shale, and 2 feet of coal. While this may be the No. 7 coal without its usual thickness and limestone roof, this test is not conclusive. It is noted under "Stratigraphy" (p. 215) that near Eldorado, coal No. 7 occurs 200 feet below a limestone which may possibly, but not probably, prove to be the Carthage. If the same interval holds at Round Pond, coal No. 7 should occur where the section is now filled with clay and gravel. Its presence in workable thickness can be determined by a test hole at a point on the hill slope located above this well, so as to avoid the surface clays.

Loc. 27: Though the 25-foot sandstone cliff here has the same elevation as a similar bed in the section at loc. 23, and may indicate absence of dip, the evidence is not strong enough to be trustworthy.

*Locs. 28-35*—Near Norris City stratigraphic notes are obtainable from three diamond-drill logs and from hill outcrops, as shown in fig. 2. The altitudes of coal No. 7 in the test borings indicate a dip N. 5° W. of 48 feet to the mile, but the outcrops indicate in the area to the northeast a dip of the same amount N. 26° W. The calculations are based on a cinnamon-brown sandstone and certain thin coals.

Loc. 31: The rocks exposed at the hilltop consist of 10 feet of gray sandstone over 15 feet of brown shale. A few rods to the north, at the crossroads, occur the underlying beds, consisting of cinnamon-brown sandstone 10 feet thick which overlies 20 feet of ferruginous clay shale.

Loc. 32: In a gully west of the road this same sandstone is exposed with its accompanying shale.

Loc. 33: The railroad cut reveals 25 feet of shale and sandy shale, probably occurring 40 feet below the brown sandstone mentioned.

Locs. 34-35: The thin coal 8 feet below the surface at loc. 34 is probably identical with the lower one of two which occur 35 feet apart on the Henson farm at loc. 35 and with the first coal in the boring at loc. 30.

*Locs. 36-37*—Beds which are probably well above the Carthage limestone, but of which the horizons are uncertain, occur in the hill west of Norris City and at Gossett. At loc. 36 sandstone and shale partially exposed for 80 feet resemble those beds east of Norris City. At loc. 37 a 10-foot sandstone overlies fire clay which half a mile farther north occurs over a thin coal. A uniform dip from borings south of Texas City to Norris City would bring coal No. 5 about 675 feet below the railroad at Gossett.

*Loc. 38*—West of Broughton, on the land of J. T. Barker, a thin coal which outcrops at an altitude of 430 feet is overlain by fire clay and a band of limestone. A 3-foot limestone which lies 32 feet below the coal in a shaft at this point contains typical Carthage fossils and suggests that coal No. 7 should occur 275 feet below it and No. 5 120 feet lower. Since the evidence is not conclusive, coal No. 5 may lie much lower yet.

*Locs. 39-43*—Thin coals are struck in a number of wells near Broughton at an altitude about the same as the coal at loc. 38, but it is impossible to identify them or to calculate the depths to workable coals at these points. The occurrences are on the farms of Messrs. Roberts, William Stevens, Golson, C. H. Francis, and Grifin.

*Loc. 44*—Southwest of Roland occurs a 3-foot limestone which on lithologic and fossil evidence is probably the Carthage. Coal No. 7 should be reached about 275 feet below it and No. 5 120 feet lower. As this is much less than the depth at Norris City and Omaha, this vicinity would seem to be a favorable place to prospect.

*Loc. 45*—Exposures 50 feet higher than at loc. 44 show a sandstone which overlies sandy shale and which probably is identical with that occurring along the Little Wabash, 110 feet above the Carthage limestone. This would indicate a dip of 60 feet from loc. 44 to loc. 45.

*Locs. 46-47*—Limestone is reported in wells to the south at an altitude about 35 feet lower than the Carthage at loc. 44.

*Loc. 48*—The Omaha well struck at 403 feet a thick coal, which is overlain by 4 feet of limestone and probably is coal No. 7. Another limestone, doubtfully reported 223 feet above it, is possibly the Carthage limestone.

*Locs. 49-50*—The Carthage limestone and the upper limestone are probably exposed south and east of Elba, and offer a basis for calculating the altitude of workable coals. At loc. 49 a section of 45 feet is exposed with a 4-foot limestone, probably Carthage, at the base, altitude 343 feet; a 3-foot sandstone at the top; and brown shale between. The beds dip upstream about 1 foot in 40. At loc. 50 a 17-foot section of shale and sandstone shows, 4 feet above the base, a thin bed of limestone and iron ore, at an altitude of 348 feet, but probably lying 50 feet above the Carthage. The dip is to the east, 1 foot in 50.

*Locs. 51-69*—The following observations were made between Elba and Equality:

*Summary of observations at locs. 51-69.*

| Loc. No. | Name. | Kind of Rock. | Thickness. Ft. | Thickness. In. | Depth. Feet. | Altitude. Feet. | Geologic horizon. |
|---|---|---|---|---|---|---|---|
| 51 | —— McCormick | Limestone | ............ | | 52 | 340 | Carthage (?). |
| 52 | H. G. Morton | Shale, coal | | + | 23 | 375 | |
| 53 | John Burton | Coal | | 4 | 60 | 340 | |
| 54 | —— Johnson | ..do | | + | 31 | 380 | |
| 55 | ........................ | ..do | | + | 21 | 330 | |
| 56 | W. A. Wathen | Limestone | + | | 25 | 365 | 125 or 50 feet over No. 7. |
| 57 | F. M. McLean | ..do | ............ | | 36 | 350 | |
| 58 | Broughton Temple | Coal | + | | 80 | 280 | No. 7. |
| 59 | John Nave | ..do | + | | 90 | 315 | No. 7. |
| 60 | —— Percil | ..do | + | | 90 | 315 | No. 7. |
| 63 | ........................ | Shale | 15 | | 0 | 355 | Over No. 6. |
| 64 | Frank Hamel | Black shale | + | | 130 | 250 | Over No. 5. |
| 65 | John Davenport | ..do | + | | 130 | 250 | Over No. 5. |
| 66 | —— Beatty | Coal | | + | 47 | 335 | No. 6. |
| 68 | —— Siebman | ..do | | 18 | 65 | 335 | (?) |
| 69 | John Hish | Coal | | 2 | 0 | 350 | |
| | | Limestone, coal | | 4 | 93 | 257 | No. 7. |

*Loc. 70*—In the 250-foot well of Louis Drone five coals, 18 inches to 10 feet thick, are reported. The thickest bed, probably No. 7, was reached 188 feet down, or at an altitude of 115 feet.

*Loc. 71*—Joseph Devous's test hole strikes a coal with limestone roof, probably No. 7, at 380 feet and another, probably No. 5, at 484 feet.

*Locs. 72-73*—Test borings of Vandell Mining Company.

*Loc. 79*—The following outcrop occurs above the railroad at Equality:

*Section at Equality.*

| | Feet. |
|---|---|
| Sandstone, coarse, gray, micaceous | 10 |
| Shale, light gray | 18 |
| Coal, No. 6 | 2 |
| Fire clay | 1 |
| Sandstone and shaly sandstone | 4½ |
| Railroad level. | |

*Loc. 81*—The altitude of an outcrop of the roof limestone of No. 7 coal at Equality, compared with data given on the mine map of the Gallatin Coal Company, shows an interval of 117 feet between coals Nos. 7 and 5.

*Loc. 82*—A 156-foot well on the Charles Manel farm probably passes the horizon of coal No. 7, filled with surface clay, and stops just short of coal No. 5.

*Loc. 83*—The Pearce well reaches an 18-inch coal, possibly No. 6, at a depth of 77 feet, or an altitude of 283 feet.

*Loc. 84*—Coal test boring of Davenport Coal Company.

*Locs. 85-87*—Test borings of O'Gara Coal Company.

*Locs. 88-89*—West of Cottage Grove a 2-foot limestone, probably 50 feet over coal No. 7, is reached in a well and also outcrops under a 5-foot sandstone and over fire clay.

*Loc. 91*—A well reaches coal No. 7 at 365 feet altitude.

*Loc. 92*—A. D. Robinson's well reaches a 6-foot coal bed at 124 feet, or at 270 feet altitude. It underlies a limestone and is probably coal No. 7.

*Loc. 95*—Test boring of National Mining Company.

*Locs. 97-102*—Wells east and south of Eldorado strike limestones at about the Carthage horizon, and these, together with certain coals, seem to indicate a northeasterly dip. A summary follows:

*Summary of observations at locs. 97-101.*

| Loc. No. | Name. | Kind of Rock. | Depth. | Altitude. |
|---|---|---|---|---|
| | | | *Feet.* | *Feet.* |
| 97 | Tim Sisk | Coal | 100 | 325 |
| 98 | | Limestone | 52 | 348 |
| 99 | C. A. Jones | Limestone | 40 | 350 |
| | | Coal, thin | 100 | 290 |
| 100 | Philip Collins | Limestone | 55 | 360 |
| 101 | J. E. Westbrook | Limestone? | 27 | 380 |

*Locs. 103-107*—Test borings of O'Gara Coal Company.

*Loc. 108*—Test boring of Wabash Petroleum Company, depth 1,093 feet, dry.

*Locs. 109*—Gas well of W. T. Overton.

*Locs. 110-114*—Coal test borings of Eldorado Mining Company, Terre Haute, Ind. Records not furnished for use of the Survey.

## COAL RESOURCES.

This region produced 314,927 tons of coal in 1906, a gain of 115 per cent over 1905. Saline and Gallatin counties combined produced 1,069,425 tons in 1906, gaining 58 per cent over the preceding year.

As already described, and as indicated by the columnar sections in Pl. 10, coals occur at twenty horizons at least, but many of these are local in extent and worthless. Only two beds are now mined, Nos. 7 and 5, but inasmuch as three or more lower coals are workable in adjoining areas to the south and east and in other parts of Illinois, it seems likely that drilling may show similar conditions in parts of this region.

### EXTENT OF COAL DEPOSITS.

The areal extent of workable coals has been only partly determined, for the persistence of thick beds in the area untested by borings is uncertain; the presence and depth of preglacial valleys is concealed by overlying deposits of glacial drift and of alluvium; and, in addition, it is possible that structural movements may have exposed the coals to preglacial erosion to a degree not now suspected.

In the New Haven quadrangle coals Nos. 7 and 5 will very probably prove to be workable. Their horizons undoubtedly occur under the various hill tracts indicated on Pl. 9, and, in the absence of evidence to the contrary, presumably also under the intervening areas,

which are covered by glacial and fluvial deposits. The only information serving to indicate their probable depth below the surface is offered by the outcrops of the supposed Carthage limestone and other related beds at the locations indicated on the map. Though the thickness of the beds here is doubtful, they are generally workable in western Kentucky. They are mined near the southeast corner of the quadrangle at Morganfield, and they are presumably minable also at Mount Vernon, Ind., near the northeast corner, at depths of 625 and 710 feet respectively.* In view of these facts and the general thick development of these coals under the Eldorado quadrangle, it seems likely that they are workable under most of this area also unless preglacial erosion lines are deep and extensive.

Under the Eldorado quadrangle coal No. 7 is probably everywhere present except in a small area along the south margin, as indicated by its outcrop shown on Pl. 9. It is absent in the southwest corner in borings at locs. 85-87, and has ben eroded from the middle of the valley, separating the hills at Cottage Grove and Equality. From the latter place it is absent to a point a little east of locs. 75 and 76, where it reappears. The presence of the coal southward from Equality to the Gold Hill Range is doubtful, because of the probability of structural irregularities and preglacial erosion. Coal No. 5 has similar but somewhat greater extent than No. 7. It is known to extend beyond the margin of the Eldorado quadrangle in the southwest corner. East of Equality it is absent for a short distance between North Fork of the Saline river and locs. 75 and 76, also for a short distance farther east. This statement presupposes that the changes in altitude of the rock between Equality and Junction are due, not to a fault, but to uniform dips.

## DESCRIPTION OF COALS NOW MINED.

Of the coals now worked, to judge from chemical analyses and from the physical conditions of the beds and their overlying and underlying rocks, No. 5 is more valuable than No. 7, though the latter is nevertheless an excellent bed.

### *Coal No. 5 (Harrisburg Coal).*

Coal No. 5, which is identical with No. 9 in Kentucky, is extensively mined at Harrisburg, Eldorado, Equality and near-by points, as shown by the accompanying table of mines (p. 229). It lies about 100 feet below coal No. 7, and probably about 390 feet below the Carthage limestone. It is about 90 feet above coal No. 4 and 430 feet or more above the Caseyville conglomerate.

The uniform thickness and purity of the bed is characteristic. As observed or reported at 56 places in the area, it averages 4 feet 11 inches in thickness; at only two of these is it less than four feet, and at two it exceeds six feet. Based on the average thickness of this coal and a specific gracity of 1.3, as determined for one sample, each acre underlain by it contains about 8,700 tons. The coal is either

*Core record of Mount Vernon Coal and Mining Company.

lustrous or dull black, and here and there streaked with "mother coal" or "mineral charcoal." Only a few bands or patches or sulphur are present, and while these are most likely to occur near the top of the bed, they are merely local features. The coal ranges from rather hard and tough to soft and brittle, and has a hackly fracture.

The mining conditions of coal No. 5 are excellent. The roof is a hard shale, which usually stays up well without excessive timbering. It is characterized by the presence of pyrite balls, or "niggerheads," and more rarely is associated with thin bands of limestone within two or three feet of the coal. In several mines the shale adheres closely to the coal, and some falls with it. Beneath the bed occurs a thin layer of fire clay. The coal is easily cut in all directions, there being no strong development of face or butt cleats. In a few mines this bed generates inflammable gas, but it is not dangerous under normal mining conditions.

Analyses of coal No. 5 and of one coke sample from this bed are given in the table on page 228. At Dekoven, Ky., this coal is coked extensively after washing. At Equality the Gallatin Coal and Coke Company converts its slack into coke, which is marketable, although somewhat higher in ash and sulphur than is desired. Experiments are now in progress looking to improvement of the quality. As Illinois produces no coke except from this bed, so far as shown by published reports, thorough experiments with it are very desirable.

### *Coal No. 7 (Equality Coal).*

Coal No. 7 is mined for shipment at Norris City and for home use at two small mines near Equality, where the bed outcrops. It is identical with coal No. 11 of Kentucky. The position of the bed is approximately 50 feet below coal No. 8, 55 feet above coal No. 6 and 90 to 128 feet above coal No. 5. It is thought to lie about 275 feet below the Carthage limestone and 550 feet or more above the Caseyville conglomerate.

The average thickness of the bed, as reliably indicated at 61 places in the area, is 4 feet 4 inches. In seven of these localities it is less than four feet thick, and in four others is practically absent. Present data indicate that the areas of thin coal are only local, and that there is no definite tendency to thin out in any particular direction. Thus the coal may be well developed within three-fourths of a mile from points where borings show it to be relatively thin. At Norris City, where the greatest measurements were obtained, the bed ranges from 5 feet 9 inches to 6 feet 6 inches. The coal is lustrous black, and where seen is tender and brittle. The high quality of the coal itself is impaired by a persistent band of clay shale, which ranges from half an inch to three inches, and averages about two inches in thickness. This occurs from 12 to 24 inches above the fire clay, but usually about 18 inches. From 6 to 10 inches below the top of the coal there is also a rather persistent sulphur streak, which is usually less than one-half inch thick, but may measure one inch. A few other patches or streaks of sulphur occur locally through the bed. Analyses of coal No. 7 appear in the accompanying table.

The mining conditions of this bed, though not known from extensive operations, are apparently good. A layer of black shale, varying in thickness up to 17 inches, and locally banded, separates the top of the coal from a limestone that is from four to seven feet thick. However, sandstone is said to overlie and partly cut out the coal at places in the mine at loc. 67. Care is necessary to prevent the shale from falling with the coal. The bed is underlain by one to five feet of fire clay. Here and there small rolls or horsebacks are present, and the character of the roof and floor is such that squeeze or creep is liable to occur unless care is exercised in mining.

### CHEMICAL ANALYSES OF THE COALS.

The accompanying analyses indicate that the coals of this area rank with the very best of the State. The several results, however, are not equally suited for close comparison with other analyses, since some represent samples which were taken and analyzed under unknown conditions, and even though they may have been, when fresh, truly representative of the several mines, they are not known to have been similarly handled, either to preserve the normal moisture content or to expel part or all of it. Higher efficiency, of course, is shown by dried samples, other things being equal, than by those which contain moisture. Varying amounts of time elapsed between taking and analyzing the several samples, and it has been shown by chemists at the State Geological Survey that those which stand long before analysis lose volatile matter when opened, and that the resulting efficiency determinations are really lower than they should be. The analyses here presented were obtained under the conditions described below.

Analyses 1, 14, 17 and 18 were made by W. F. Wheeler of the State Geological Survey from samples collected by the writer in the following manner: A clean exposure, representative of the average condition of the bed, was grooved from top to bottom and the sample collected on clean oilcloth. No impurities were thrown out except those usually excluded from commercial shipments. The sample was further prepared in the mine or at the surface by crushing, mixing, quartering and sealing in an air-tight can as quickly as possible, in order to preserve the normal moisture of the coal. Analyses were made after four or five months.

Analysis 1 represents a sample from the end of the first west entry off the main south entry, about 1,000 feet from the shaft, where the coal measures 4 feet 6 inches. The sample was prepared in the mine without excluding impurities and was immediately sealed on reaching the surface. It is probable that some extraneous water reached the sample while ascending the shaft.

Analysis 14 represents the bed at the end of the first main north entry, 400 feet from the shaft, where it has a thickness of 5 feet 4 inches. A little of the sulphur showing at this place was excluded from the sample. The coal was prepared and sealed promptly above ground.

Analysis 17 represents the coal at the end of the first entry off the main entry, where it measures 4 feet 7 inches, and shows no impurities which are excluded from shipment. This sample was prepared and sealed within five minutes after leaving the mine.

Analysis 18 represents coal taken at the country mine of Mr. Dobbin, where the following section was measured:

| | Feet. | Inches. |
|---|---|---|
| Limestone | 4 | 6 |
| Shale | 1 | |
| 1. Coal | | 6 |
| 2. Sulphur and shale | | ½ |
| 3. Coal | 2 | 7 |
| 4. Shale | | 2½ |
| 5. Coal | | 10 |
| Fire clay | 4+ | |
| Total coal bed | 4 | 2 |

Impurities from layers 2 and 4 are picked from the coal before marketing and are excluded from the sample.

Analyses 8, 13 and 16 were made by W. F. Wheeler, of the State Geological Survey, from samples collected by F. F. Grout in the manner described. When analyzed, these samples had stood sealed for eleven months.

Analysis 8 represents a sample taken in the second room off the second west entry, where the coal measures 56 inches thick and shows no persistent bands.

Analysis 13 represents the coal in the first room off the second east entry on the north, where the following section was measured:

*Section in O'Gara Mine No. 12.*

| | Inches. |
|---|---|
| Shale, pebbly (many feet) | |
| Draw slate, second | 5 |
| Draw slate, first | 7 |
| 1. Coal | 27 |
| 2. Sulphur | ⅛—1 |
| 3. Coal | 32 |
| Fire clay. | |
| Total coal bed | 60 |

The sample includes layers 1 and 3. No. 1 has two partings of sulphur three inches and eight inches from the top which are not persistent but are common in the mine.

Analysis 16 was made from a sample obtained near the shaft, which includes Nos. 1, 3 and 5 of the following measured section:

*Section in Mine of Norris City Coal Company.*

| | Ft. | In. |
|---|---|---|
| Limestone | 4 | 6 |
| Shale | | 2-16 |
| 1. Coal | | 7 |
| 2. Sulphur | | ½ |
| 3. Coal | | 31 |
| 4. Blue band | | up to 3 |
| 5. Coal | | 18 |
| Fire clay. | | |

Analysis 2 to 7, inclusive, by Prof. S. W. Parr, of the State University of Illinois, were recently published in Bulletin No. 3 of the State Geological Survey. The samples were collected in canvas bags at the mines from the surface of car lots prepared for shipment, and were sealed in air-tight jars in the laboratory. Since the moisture of the samples after shipment differed presumably by varying amounts from that shown under normal conditions in the mines, analyses were preceded by air drying.

Of analyses 9, 10, 11 and 12, kindly furnished by Superintendent Thomas, of the O'Gara Coal Company, No. 9 was made by Professor Parr and the others by various private chemists. The exact method of sampling and treatment before analysis is not stated.

Analysis 15, made by the General Chemical Company, of Chicago, was obtained through the courtesy of Supt. J. B. Kitch, of the National Mining Company. The percentage noted in the sulphur column includes "sulphur and waste."

Analysis 19 and 20, made by Regis Chauvenet & Bro., of St. Louis, for the Gallatin Coal and Coke Company, were kindly furnished by President Hugh Murray.

*Analyses of Coal and Coke from Saline-Gallatin Field, Illinois.*

| | No. on Pl. VIII or IX? | Mine. | No. of bed. | Size. | How obtained. | Condition. | Moisture | Ash. | Volatile matter. | Fixed carbon | Sulphur. | British thermal units. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 116 | O'Gara Coal Co. No. 10 (Eldorado Coal and Coke Co.) | 5 | .......... | Face cut | As mined | 8.43 | 8.85 | .......... | .......... | 1.98 | 12,026 |
| 2 | 116 | ..do | 5 | Lump | Car | Air dry | 5.68 | 8.90 | 33.32 | 52.10 | 1.18 | 12,668 |
| 3 | 116 | ..do | 5 | Slack | ..do | ..do | 4.36 | 23.58 | 29.36 | 42.70 | 2.00 | 10,400 |
| 4 | 116 | ..do | 5 | ..do | ..do | ..do | 5.04 | 10.88 | 34.36 | 49.72 | 4.00 | 12,179 |
| 5 | 116 | ..do | 5 | ..do | ..do | ..do | 4.00 | 20.88 | 30.78 | 44.34 | 3.70 | 10,924 |
| 6 | 119 | O'Gara Coal Co. No. 1 (Diamond Coal Co.) | 5 | Lump | ..do | ..do | 4.10 | 6.76 | 37.17 | 51.97 | 1.55 | 12,949 |
| 7 | 119 | ..do | 5 | Slack | ..do | ..do | 4.72 | 14.28 | 32.72 | 48.28 | 2.70 | 11,351 |
| 8 | 115 | O'Gara Coal Co. No. 8 | 5 | .......... | Face cut | As mined | 6.93 | 8.12 | .......... | .......... | 1.69 | 12,298 |
| 9 | 115 | ..do | 5 | .......... | Not known | Not known | 2.31 | 7.67 | 34.75 | 55.27 | .53 | 12,678 |
| 10 | 115 | ..do | 5 | .......... | ..do | ..do | 4.84 | 6.26 | 29.59 | 57.80 | 1.51 | .......... |
| 11 | 115 | ..do | 5 | .......... | ..do | ..do | 4.64 | 6.32 | 31.24 | 57.80 | 1.50 | .......... |
| 12 | 115 | ..do | 5 | .......... | Face cut | ..do | 2.37 | 11.28 | 30.07 | 56.28 | 2.16 | 12,849 |
| 13 | 120 | O'Gara Coal Co. No. 12 (Harrisburg and Big Muddy Coal Co.) | 5 | .......... | ..do | As mined | 5.38 | 8.47 | .......... | .......... | 2.40 | 12,475 |
| 14 | 96 | National Mining Co | 5 | .......... | ..do | ..do | 4.69 | 11.74 | .......... | .......... | 4.03 | 12,211 |
| 15 | 96 | ..do | 5 | .......... | Not known | Not known | .......... | 7.18 | 38.16 | 54 66 | 3.03 | 13,000 |
| 16 | 28 | Norris City Coal Co | 7 | .......... | Face cut | As mined | 7.97 | 10.73 | .......... | .......... | 2.68 | 11,512 |
| 17 | 77 | East Side Coal Co | 5 | .......... | ..do | ..do | 4.30 | 10.74 | .......... | .......... | 4.36 | 12,452 |
| 18 | 93 | Dobbins bank | 7 | .......... | ..do | ..do | 5.73 | 11.19 | .......... | .......... | 3.13 | 12,177 |
| 19 | 80 | Gallatin Coal and Coke Co | 5 | .......... | Not known | Not known | 1.91 | 9.75 | 34.99 | 53.35 | 2.14 | .......... |
| 20 | 80 | ..do | 5 | Coke | ..do | ..do | 0.00 | 15.61 | 1.43 | 82.96 | 2.28 | .......... |

DESCRIPTION OF COAL MINES.*

The appended table presents a list of the coal mines of this area. Inasmuch as the district includes old and new mines, both primitive and modern methods of mining are employed. This paper does not review in detail the technology of these mining methods, but merely outlines prevalent or important conditions.

In the mines visited,† which are laid out according to various adaptations of the room-and-pillar plan, pick mining prevails, and the coal is shot down, then hauled in wooden cars of one to two tons capacity, by mules. Usually the shafts are divided into two parts, nine by fourteen feet each, and are provided with single-decked cages of metal construction, with safety clutches. The most popular hoisting engine is one that acts directly on a six-foot drum. The coal dumps automatically into scales and into shaker or revolving screens. Box car loaders are employed to a small extent. The mines require little pumping, and some need sprinkling in certain seasons. Ventilation is usually effected by Capell propelling fans about twelve feet in diameter. Speaking tubes between engine room and shaft bottom are installed in a few mines, and electric lights are also used underground by the National Mining Company.

Screened coal chiefly is shipped, and although no figures were collected to show the sizes made it is estimated that in some cases as much as 30 per cent is slack. This condition is almost certain to be remedied by the introduction of machine mining. As already stated, at Equality the slack of coal No. 5, after washing, makes a marketable coke, and the further development and perfection of this process is thought to promise much for this field.

*Partial List of Coal Mines in Saline-Gallatin Field, Illinois.*

| Name of mine or owner. | No. on Pl. VIII or IX? | Location. | Character of opening. | No. of bed. | Average thickness. | Depth to base of coal. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | | | | *Ft. In.* | *Ft.* | |
| Slaten | 90 | Cottage Grove | Slope | 7 | 4 4 | .... | Abandoned. |
| Dobbin | 93 | Northwest of Equality | Shaft | 7 | 4 2 | 57 | Local. |
| East Side Coal Co | 77 | Equality | ..do | 5 | 4 7 | 40 | |
| Gallatin Coal & Coke Co | 80 | ..do | ..do | 5 | 4 10 | 80 | |
| Gold Nugget | 78 | ..do | ..do | 5 | 4 7 | 40 | |
| Gordon | 67 | Northeast of Equality | Slope | 7 | 4 2 | 41 | Local, suspended. |
| Hargrave | 75 | East of Equality | Drift | 5 | 4 3 | .... | |
| McLain | 61 | North of Equality | ..do | 7 | 4 2 | .... | Local. |
| National Mining Co | 96 | Southeast of Eldorado | Shaft | 5 | 5 4 | 336 | |
| Norris City Coal Co | 28 | Norris City | ..do | 7 | 5 4 | 640 | |
| O'Gara Coal Co., No. 1 | 119 | 4 miles southwest of Eldorado | ..do | 5 | ........ | 302 | |
| O'Gara Coal Co., No. 8 | 115 | Eldorado | ..do | 5 | 4 6 | 407 | |
| O'Gara Coal Co., No. 10 | 116 | ..do | .do | 5 | 4 6 | 511 | |
| O'Gara Coal Co., No. 11 | 117 | ..do | ..do | 5 | 4 6 | 404 | |
| O'Gara Coal Co., No. 12 | 120 | 5 miles southwest of Eldorado | ..do | 5 | ........ | 421 | |
| Percil | 62 | North of Equality | Drift | 7 | 4 2 | .... | Abandoned. |
| Sanks | 76 | East of Equality | Slope | 5 | 4 4 | 28 | Local. |
| Swinney | 94 | Northwest of Equality | Shaft | 7 | 4 2 | 30 | Suspended. |
| Vandell Mining Co | 74 | Junction | ..do | 7? | ........ | .... | Sinking shaft. |
| Wasson Coal Co | 118 | 1½ miles southwest of Eldorado | ..do | 5 | ........ | 328 | ..do |

*These mines now (1908) are largely equipped with chain machines for undercutting, and with motor haulage, electric lights and other improvements.

† The mines at locs. 80, 119 and 120, which lie beyond the borders of the quadrangles proper, were not examined personally in this preliminary work.

# Coal Investigations in Saline and Williamson Counties, Illinois.

(By Frank W. DeWolf.)

## Introduction.

The area described in this report includes part of the Harrisburg field in Saline county and a smaller district in Williamson county which adjoins on the west. The accompanying map (plate 11), which comprises the southern half of the Galatia quadrangle and some additional area on the south and on the west, includes approximately 100 square miles near the southern edge of the Illinois coal fields.*

The growing importance of the region is demonstrated by the increase in coal production, as given by the U. S. Geological Survey, for during the year ending December 31, 1907, Saline county produced 2,247,202 tons as compared with 980,864 tons for 1906. Coal of a quality doubtfully equaled in the State underlies practically all of the area examined, and within a moderate depth of the surface. Consolidation of mining interests which has been extensively effected here during the last two years has accompanied the installation of new mining equipment, the opening of new properties and prospecting with the diamond drill on a scale rarely attempted. The area is bound to become a large factor in the production of the State under favorable market conditions.

This paper is published as a progress report of a continuous survey which is being extended across the State from near Mt. Vernon, Indiana, to Murphysboro on the west. The area is being mapped in six rectangular units or "quadrangles" and field work will be largely completed in 1908. The Galatia is the third quadrangle surveyed and joins the west side of the Eldorado. The geology and coal resources of the areas already studied is described in this volume and has been recently published elsewhere.* Both topographic and geologic mapping is being executed in coöperation by the State Geological Survey and the United States Geological Survey.

The writer wishes to acknowledge the valuable assistance of Mr. A. J. Ellis, in the collection and study of geologic data and of Mr. W. F. Wheeler and Mr. J. M. Lindgren in the study of coal composition, under the direction of Prof. S. W. Parr. The work of the Survey has only been possible through the cordial coöperation of those local coal operators who permitted the use of private bore records, especially The Guarantee Trust Company, The O'Gara Coal Company, The Peabody Coal Company and The Harrisburg Coal Company.

*U. S. Geological Survey, Bulletin No. 316, 1906; See also this bulletin, pp. 211-229.

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### Influence of Relief and Drainage.

The favorable nature of the relief as affecting present and future development is presented with accuracy by the Galatia topographic map,* which shows also the position of roads, houses, and public land lines. The eastern part of the area consists mostly of nearly flat land which lies about 365 feet above sea level and is frequently subjected to head water floods, and at long intervals to back water from the Ohio river. Above this rise small remnants of an old upland, which in the western part of the area reaches some 100 to 250 feet above the low land and is thoroughly dissected by ravines.

Transportation is now accomplished by railroads which cross the low eastern part of the area, but the region must remain handicapped until the large hilly tract to the west is brought into reach of markets. This situation will be improved by the railroad now being constructed between Harrisburg and Galatia and the projected line from Eldorado to Pittsburg, in Williamson county. Both Bankston and Brushy creeks offer excellent grades for reaching the heart of the upland by railroads from Harrisburg, since they rise but 70 and 100 feet respectively in reaching the western edge of the area mapped and this would amount approximately to one foot to each 650 feet along an air line route.

## Geology.

### introduction.

As a thorough investigation of the coals of the region involves also the associated strata, an attempt was made to collect all information bearing on the stratigraphic and structural relations. Particular attention was given to each coal of commercial importance, so as to determine its varying thickness and depth in the areas underlain, and as far as possible the dip of the bed as affecting ease of exploitation. The condition of origin of the coals has been studied and promises to explain their local absence, and to assist the commercial development. On account of the thick surficial deposits the hard rocks of the area outcrop rarely and contribute little to the investigation. The great number of drill records, however, has made it possible to determine many facts of economic and scientific interest. The notes of first importance, commercially, are here presented with a provisional map (plate 11.)

### Stratigraphy.

The rocks underlying the surface clays, as explored to a depth of about 1100 feet, consist of alternating beds of shale and sandstone, with relatively thin and more or less local beds of limestone, coal and fire clay. All the rocks appear to belong to the Pennsylvanian series of the Carboniferous system. The Carthage limestone, which has been used in the past to separate the carboniferous into Upper and Lower Coal Measures† is probably present 80 feet from the top of the

*Copies may be obtained for five cents each by addressing the Director U. S. Geological Survey, Washington, D. C.

†See page 213.

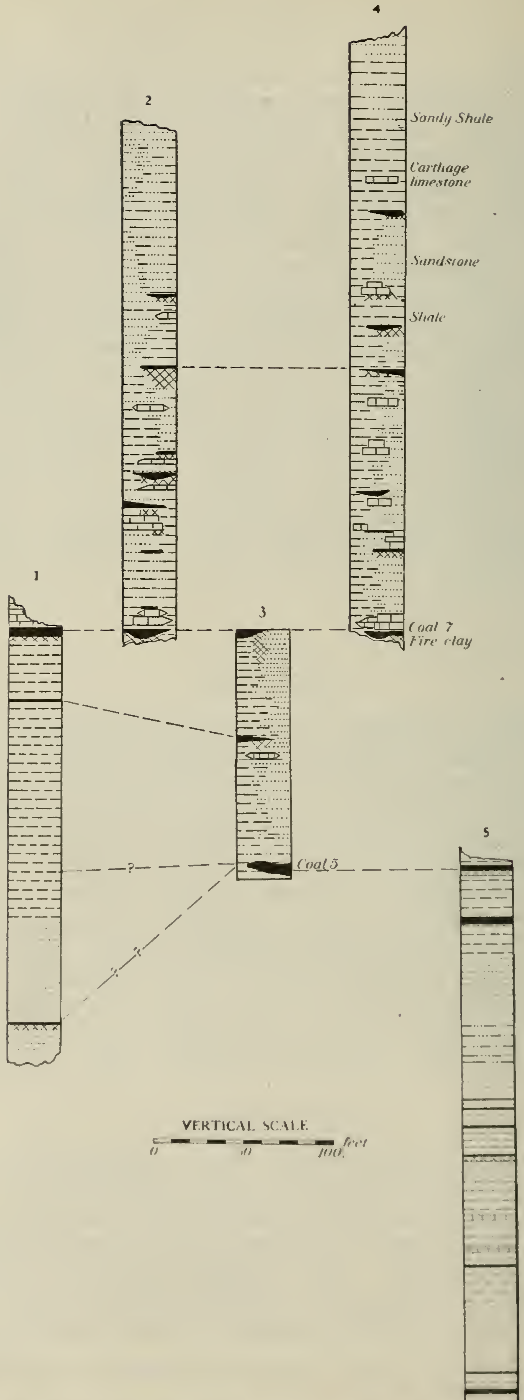


Fig. 19. Representative columnar sections in the Williamson-Saline coal field.

strata here described, and is shown in Section 4 (Fig. 19) with accompanying beds similar to those of the Eldorado quadrangle. As the strata closely resemble those of the area on the east already described* but few additional notes are required at this time. The accompanying columnar sections are based on abundant data covering the strata extending 300 feet above Coal No. 5. Above this distance the rocks are not so well known, so the illustrations are of less value. Below Coal No. 5 a number of borings show some common features, but such general disagreement as to prevent satisfactory correlation without reference to additional records from adjoining areas which have not yet been studied. A single hole which penetrates approximately 600 feet below Coal No. 5 reaches about to the base of the Pennsylvania rocks, but the record obtained appears unreliable as to details and is not published.

The correlation of certain beds is well established, especially of Coals Nos. 7 and 5. They have a wide persistence, occurring generally throughout the area surveyed, and are identical with Coals Nos. 11 and 9 of the Western Kentucky sections, and probably with Coals VII and V of the Indiana Survey. The work of the Survey has already proved the identity of No. 7 with No. 6 of the Belleville area and No. 7 of Williamson and Franklin counties. Other coal beds shown in the sections having well defined horizons are locally either present or absent, and their detailed distribution has yet to be studied. Of the limestones, that overlying Coal No. 7 and another about 45 feet higher, are horizon markers of wide extent. The sandstones and shales give way to each other from place to place and the horizons have a tendency to show one or the other as illustrated by the relative prominence of the respective symbols in the generalized sections (Fig. 19.)

Certain features of the stratigraphy are of special interest. The beds between Coals Nos. 7 and 5 are of the character indicated by section 3 (Fig. 19) and the interval from base to base is remarkably constant at from 100 to 140 feet. The two coals are not exactly parallel however, and the extreme variation in interval is worth note. About 30 records report 90 to 100 feet in the area extending from the southwest corner of the map (plate 11), to Section 9, T. 8, R. 5. A similar number show that the interval exceeds 140 feet in parts of the land in Range 9 and extending from Harrisburg westward nearly to the Williamson county line. A number of these latter report a value exceeding 170 feet and in three logs an interval of 205 to 220 feet is possibly indicated. One of the latter records is shown as section 1 (Fig. 19) to represent the dozen or more records of questionable interpretation. It suggests the possibilities, either that the interval is much greater than usual or that the lower coal is at a horizon below No. 5. In many test holes there appears to be a heavy sandstone at the horizon of No. 5 and this is more or less continuous with another sandstone the top of which, in a few records, is definitely indicated to lie about 80 feet below No. 5. In such cases the question arises as

*See page 214.

to whether No. 5 is much farther below No. 7 than usual or whether No. 5 is absent because of either non-deposition or contemporary or later erosion, and replacement by sandstone. Decisive evidence on these points is believed to be available on further study. Of eight holes which clearly show the presence of No. 5 and penetrate still deeper, all show at least two lower coal horizons. Three indicate a coal from 30 to 50 feet below No. 5 and separated from it by fire clay and sandy shale, but the deep coals of the remaining five records cannot be correlated with one another or with the deep seams reported in the area to the east. Section 5 (Fig. 19) represents the deepest reliable log and shows a four foot bed 300 feet below No. 5, and several thin seams intervening.

## STRUCTURE.

The attitude or structural relations of the coal is a large factor in determining the expense of mining, since it affects ease of haulage, drainage, and ventilation. The coals and associated strata of this region, which are essentially parallel with one another, are in some places nearly horizontal, but in others appear to slope or dip in varying directions and amounts, or to be displaced along fault planes. The accompanying map attempts to show by contours the varying elevation of Coal No. 5 above sea level. The method of construction and the use of the map along with its limitations, may be discussed here. The elevation of the ground above sea level was determined at each test boring and mine shaft and from this figure was subtracted the depth of Coal No. 5 in order to obtain its altitude. Where the coal lies at different altitudes at adjoining locations, the dip between them is regarded as uniform and points of equal altitude are connected by a contour line. The direction of dip is thus assumed to be perpendicular to the contours and the amount is 25 feet between adjoining lines. It should be understood that there are several sources of error in the map. The most important is the assumption that the dip is uniform between two neighboring datum points, whereas the beds may lie horizontal for part of the distance and steeply inclined for the remainder or even displaced by faulting. Another error of minor importance has doubtless resulted from the use of barometer and hand level for determining surface elevations. As an excellent topographic map and numerous bench marks were available for reference this error is slight, but for the benefit of local engineers who may wish to do the work with greater refinement a table of results is here presented, together with an appended table of permanent bench marks.

*Table of Surface Data.*

| Location. | | | | Elevation. | |
|---|---|---|---|---|---|
| Township. | Range. | Section. | Map No. | Ft. above sea level. | Determined by |
| 8 | 4 | 1 | 1 | 408 | *L |
| 8 | 4 | 25 | 1 | 494 | L |
| 8 | 4 | 25 | 2 | 495 | *B |
| 8 | 4 | 34 | 1 | 492 | L |
| 8 | 4 | 34 | 2 | 480 | L |
| 8 | 4 | 34 | 3 | 520 | L |
| 8 | 4 | 34 | 4a* | 549 | B |
| 8 | 4 | 35 | 1 | 530 | B |
| 8 | 4 | 35 | 2 | 522 | L |
| 8 | 4 | 35 | 3 | 533 | L |
| 8 | 4 | 36 | 1 | 443 | L |
| 8 | 5 | 7 | 1 | 425 | L |
| 8 | 5 | 11 | 1 | 405 | *B |
| 8 | 5 | 19 | 1 | 408 | L |
| 8 | 5 | 19 | 2 | 422 | B |
| 8 | 5 | 19 | 3 | 404 | B |
| 8 | 5 | 19 | 4 | 435 | L |
| 8 | 5 | 20 | 1 | 405 | L |
| 8 | 5 | 20 | 2 | 400 | B |
| 8 | 5 | 20 | 3 | 399 | L |
| 8 | 5 | 20 | 4 | 409 | B |
| 8 | 5 | 25 | 1 | 412 | B |
| 8 | 5 | 25 | 2 | 380 | L |
| 8 | 5 | 26 | 1 | 431 | L |
| 8 | 5 | 26 | 2 | 428 | B |
| 8 | 5 | 26 | 3 | 438 | B |
| 8 | 5 | 26 | 4 | 445 | L |
| 8 | 5 | 27 | 1 | 435 | L |
| 8 | 5 | 27 | 2 | 440 | B |
| 8 | 5 | 27 | 3 | 427 | B |
| 8 | 5 | 27 | 4 | 434 | L |
| 8 | 5 | 27 | 5 | 430 | L |
| 8 | 5 | 28 | 1a | | |
| 8 | 5 | 28 | 2 | 415 | B |
| 8 | 5 | 28 | 3 | 420 | B |
| 8 | 5 | 28 | 4 | 442 | L |
| 8 | 5 | 29 | 1 | 418 | L |
| 8 | 5 | 29 | 2 | 432 | L |
| 8 | 5 | 29 | 3 | 433 | B |
| 8 | 5 | 29 | 4a | | |
| 8 | 5 | 29 | 5a | | |
| 8 | 5 | 30 | 1 | 462 | L |
| 8 | 5 | 30 | 2 | 482 | B |
| 8 | 5 | 31 | 1 | 448 | B |
| 8 | 5 | 32 | 1 | 456 | L |
| 8 | 5 | 32 | 2 | 448 | B |
| 8 | 5 | 32 | 3 | 437 | L |
| 8 | 5 | 33 | 1 | 402 | L |
| 8 | 5 | 33 | 2 | 404 | L |
| 8 | 5 | 34 | 1 | 420 | L |
| 8 | 5 | 34 | 2 | 390 | B |
| 8 | 5 | 34 | 3 | 422 | L |

*Table of Surface Data*—Continued.

| Location. | | | | Elevation. | |
|---|---|---|---|---|---|
| Township. | Range. | Section. | Map No. | Ft. above sea level. | Determined by. |
| 8 | 5 | 35 | 1 | 420 | L |
| 8 | 5 | 35 | 2 | 423 | L |
| 8 | 5 | 35 | 3a | 420 | B |
| 8 | 5 | 36 | 1 | 438 | B |
| 8 | 6 | 15 | 1 | 405 | L |
| 8 | 6 | 15 | 2 | 399 | L |
| 8 | 6 | 15 | 3 | 418 | B |
| 8 | 6 | 15 | 4 | 388 | L |
| 8 | 6 | 21 | 1 | 378 | L |
| 8 | 6 | 22 | 1 | 400 | L |
| 8 | 6 | 22 | 2 | 372 | L |
| 8 | 6 | 23 | 1 | 400 | L |
| 8 | 6 | 26 | 1 | 402 | L |
| 8 | 6 | 26 | 2 | 400 | L |
| 8 | 6 | 26 | 3 | 372 | L |
| 8 | 6 | 27 | 1 | 370 | L |
| 8 | 6 | 27 | 2a | 365 | L |
| 8 | 6 | 27 | 3 | 369 | L |
| 8 | 6 | 28 | 1 | 376 | L |
| 8 | 6 | 28 | 2 | 371 | L |
| 8 | 6 | 29 | 1 | 370 | L |
| 8 | 6 | 29 | 2 | 365 | L |
| 8 | 6 | 33 | 1 | 360 | L |
| 8 | 6 | 34 | 1 | 375 | L |
| 8 | 6 | 35 | 1 | 375 | L |
| 8 | 6 | 36 | 2 | 383 | L |
| 9 | 4 | 1 | 1 | 470 | L |
| 9 | 4 | 1 | 2a | 458 | L |
| 9 | 4 | 1 | 3a | | |
| 9 | 4 | 2 | 1 | 565 | B |
| 9 | 4 | 2 | 2 | 488 | B |
| 9 | 4 | 2 | 3 | 550 | B |
| 9 | 4 | 2 | 4 | 562 | B |
| 9 | 4 | 3 | 1 | 565 | L |
| 9 | 4 | 10 | 1 | 485 | L |
| 9 | 4 | 10 | 2a | 466 | B |
| 9 | 4 | 11 | 1 | 437 | L |
| 9 | 4 | 12 | 1 | 445b* | L |
| 9 | 4 | 12 | 2 | 445 | L |
| 9 | 4 | 12 | 3 | 533 | L |
| 9 | 4 | 12 | 4 | 475b | L |
| 9 | 4 | 12 | 5a | | |
| 9 | 4 | 12 | 6 | 475 | L |
| 9 | 4 | 13 | 1 | 442 | L |
| 9 | 4 | 13 | 2 | 435 | L |
| 9 | 4 | 13 | 3 | 425 | B |
| 9 | 4 | 13 | 4 | 425 | B |
| 9 | 4 | 13 | 5 | 418 | L |
| 9 | 4 | 14 | 1 | 450 | B |
| 9 | 4 | 14 | 2 | 445 | L |
| 9 | 4 | 14 | 3 | 415 | B |

*Table of Surface Data*—Continued.

| Location. | | | | Elevation. | |
|---|---|---|---|---|---|
| Township. | Range. | Section. | Map No. | Ft. above sea level. | Determined by. |
| 9 | 4 | 15 | 1 | 458 | B |
| 9 | 4 | 15 | 2 | 495 | B |
| 9 | 4 | 15 | 3 | 443 | L |
| 9 | 4 | 15 | 4 | 435 | B |
| 9 | 4 | 16 | 2 | 495 | B |
| 9 | 4 | 16 | 3a | | |
| 9 | 4 | 21 | 1 | 455 | B |
| 9 | 4 | 22 | 1 | 465 | B |
| 9 | 4 | 22 | 2a | | |
| 9 | 4 | 23 | 1 | 455 | B |
| 9 | 4 | 23 | 2 | 460 | B |
| 9 | 4 | 23 | 3 | 435 | B |
| 9 | 4 | 23 | 4a | | |
| 9 | 4 | 24 | 1 | 418 | L |
| 9 | 4 | 24 | 2a | | |
| 9 | 5 | 1 | 1 | 377 | L |
| 9 | 5 | 1 | 2 | 397 | |
| 9 | 5 | 1 | 3 | 375 | L |
| 9 | 5 | 1 | 4 | 374 | L |
| 9 | 5 | 2 | 1 | 380 | L |
| 9 | 5 | 2 | 2 | 400 | L |
| 9 | 5 | 2 | 3 | 380 | L |
| 9 | 5 | 2 | 4 | 374 | B |
| 9 | 5 | 2 | 5 | 379 | B |
| 9 | 5 | 3 | 1 | 395 | L |
| 9 | 5 | 3 | 2 | 435 | B |
| 9 | 5 | 4 | 1 | 395 | L |
| 9 | 6 | 4 | 2 | 445 | B |
| 9 | 5 | 5 | 1 | 432b | B |
| 9 | 5 | 5 | 1 | 471b | L |
| 9 | 5 | 6 | 1 | 490 | B |
| 9 | 5 | 6 | 2 | 463 | B |
| 9 | 5 | 6 | 3 | 497 | L |
| 9 | 5 | 6 | 4 | 465 | L |
| 9 | 5 | 7 | 1 | 475 | B |
| 9 | 5 | 8 | 1 | 477 | L |
| 9 | 5 | 8 | 2a | 430 | L |
| 9 | 5 | 8 | 3 | 405 | B |
| 9 | 5 | 8 | 4 | 418 | L |
| 9 | 5 | 8 | 5 | 420 | B |
| 9 | 5 | 9 | 1 | 475 | L |
| 9 | 5 | 9 | 2 | 462 | L |
| 9 | 5 | 10 | 1 | 442 | L |
| 9 | 5 | 10 | 2 | 440 | L |
| 9 | 5 | 11 | 1 | 375 | L |
| 9 | 5 | 11 | 2 | 394 | L |
| 9 | 5 | 11 | 3 | 371 | L |
| 9 | 5 | 11 | 4 | 400 | B |
| 9 | 5 | 12 | 1a | 360 | B |
| 9 | 5 | 12 | 2 | 365 | B |
| 9 | 5 | 13 | 1a | 366 | L |
| 9 | 5 | 13 | 2 | 373 | L |
| 9 | 5 | 14 | 1 | 395 | L |
| 9 | 5 | 14 | 2 | 376 | L |

*Table of Surface Data*—Continued.

| Location. | | | | Elevation. | |
|---|---|---|---|---|---|
| Township. | Range. | Section. | Map No. | Ft. above sea level. | Determined by. |
| 9 | 5 | 15 | 1 | 428 | L |
| 9 | 5 | 15 | 2 | 383 | L |
| 9 | 5 | 16 | 1 | 410 | B |
| 9 | 5 | 17 | 1 | 408 | L |
| 9 | 5 | 18 | 1 | 419 | L |
| 9 | 5 | 18 | 2 | 404 | L |
| 9 | 5 | 19 | 1 | 421 | L |
| 9 | 5 | 19 | 2 | 423 | L |
| 9 | 5 | 19 | 3a | | |
| 9 | 5 | 21 | 1 | 390 | B |
| 9 | 5 | 21 | 2 | 395 | L |
| 9 | 5 | 21 | 3a | 395 | L |
| 9 | 5 | 21 | 4 | 400 | L |
| 9 | 5 | 21 | 5 | 400 | L |
| 9 | 5 | 22 | 1 | 400 | |
| 9 | 5 | 22 | 2 | 390 | |
| 9 | 5 | 22 | 3 | 422 | L |
| 9 | 5 | 22 | 4 | 410 | |
| 9 | 5 | 23 | 1 | 415 | L |
| 9 | 5 | 23 | 2a | b | |
| 9 | 5 | 24 | 1 | 361 | L |
| 9 | 5 | 24 | 2 | 390 | B |
| 9 | 5 | 24 | 3a | b | |
| 9 | 6 | 2 | 1 | 367 | E |
| 9 | 6 | 2 | 2 | 373 | E |
| 9 | 6 | 4 | 1 | 365 | L |
| 9 | 6 | 4 | 2 | 356 | L |
| 9 | 6 | 4 | 3 | 365 | B |
| 9 | 6 | 5 | 1a | 365 | B |
| 9 | 6 | 5 | 2 | 370 | B |
| 9 | 6 | 6 | 1 | 374 | L |
| 9 | 6 | 6 | 2 | 413 | L |
| 9 | 6 | 7 | 1 | 360 | B |
| 9 | 6 | 7 | 2 | 362 | L |
| 9 | 6 | 7 | 3 | 381 | L |
| 9 | 6 | 8 | 1 | 363 | L |
| 9 | 6 | 8 | 2 | 350 | B |
| 9 | 6 | 8 | 3 | 405 | L |
| 9 | 6 | 8 | 4 | 402 | L |
| 9 | 6 | 8 | 5 | 400 | L |
| 9 | 6 | 9 | 1 | 392 | L |
| 9 | 6 | 9 | 2 | 393 | L |
| 9 | 6 | 10 | 1a | 362 | L |
| 9 | 6 | 10 | 2 | 365 | L |
| 9 | 6 | 11 | 1 | 353 | L |
| 9 | 6 | 11 | 2 | 353 | L |
| 9 | 6 | 13 | 1 | 353 | L |
| 9 | 6 | 15 | 1 | 370 | E |
| 9 | 6 | 15 | 2 | 370 | E |
| 9 | 6 | 16 | 1a | 356 | L |
| 9 | 6 | 16 | 2 | 364 | L |
| 9 | 6 | 16 | 3 | 367 | L |
| 9 | 6 | 16 | 4 | 366 | L |
| 9 | 6 | 16 | 5 | 393 | B |

*Table of Surface Data*—Concluded.

| Location. | | | | Elevation. | |
|---|---|---|---|---|---|
| Township. | Range. | Section. | Map No. | Ft. above sea level. | Determined by. |
| 9 | 6 | 17 | 1 | 395 | L |
| 9 | 6 | 17 | 2 | 373 | L |
| 9 | 6 | 17 | 3 | 395 | B |
| 9 | 6 | 17 | 4 | 375 | L |
| 9 | 6 | 18 | 1 | 365 | L |
| 9 | 6 | 18 | 2 | 368 | L |
| 9 | 6 | 18 | 3 | 390b | L |
| 9 | 6 | 18 | 4 | 370 | L |
| 9 | 6 | 18 | 5 | 377b | L |
| 9 | 6 | 18 | 6 | 381 | L |
| 9 | 6 | 18 | 7 | 373b | L |
| 9 | 6 | 19 | 1a | | |
| 9 | 6 | 19 | 2 | 411 | L |
| 9 | 6 | 20 | 1 | 376 | L |
| 9 | 6 | 20 | 2 | 385 | B |
| 9 | 6 | 20 | 3 | 380 | B |
| 9 | 6 | 22 | 1 | 370 | E |
| 9 | 6 | 23 | 1 | 358 | B |
| 6 | 6 | 23 | 2 | 357 | L |
| 9 | 6 | 27 | 1 | 380 | B |

* (a) Location reported; (b) Log not used; (L) Hand level: (B) Barometer; (E) Estimate from topographic map.

## Permanent Bench Marks of the South Part of the Galatia Quadrangle.

The elevations in the following list are based upon the precise level line of 1906 from Duquoin, run under the direction of Mr. C. L. Sadler, assistant topographer, by Mr. F. C. Higley, levelman. The standard bench marks were stamped with figures of elevation to nearest foot.

| Description. | Altitude, Feet. |
|---|---|
| Rileyville, at milepost E. St. Louis 107 mi., Eldorado 14 mi., nail in top of west rack for emergency rail | 398.854 |
| Rileyville, 0.71 miles southeast of; 500 feet northwest of house on south side of railroad at point where county road jogs north from railroad, 30 feet north of tracks, in corner of fence, 30 feet northwest of cattle guard, iron post stamped "392 Illinois 1906" | 392.886 |
| Rileyville, 1.91 miles southeast of; at milepost E. St. Louis 109 Eldorado 12 mi., nail in top of west rack for emergency rail | 411.870 |
| Rileyville, 2.9 miles southeast of; at milepost E. St. Louis 110, Eldodorado 11 mi., nail in top of east rack for emergency rail | 417.992 |
| Galatia, 0.3 mile west of station; at Galatia Rolling Mill, in southwest foundation of "Old Elevator" on south side, 25 feet north of railroad track, aluminum table stamped "397 Illinois 1906" | 397.850 |
| Galatia, in front of station; top of north rail | 401.176 |
| Galatia, 0.18 mile southeast of; at milepost E. St. Louis, 111, Eldorado 10 mi., nail in top of west rack for emergency rail | 412.418 |
| Galatia, 1.16 miles southeast of ; milepost E. St. Louis 112, Eldorado 9 mi., nail in top of west rack for emergency rail | 386.890 |

| Description. | Altitude. Feet. |
|---|---|
| Raleigh, 1.59 miles east of; 70 feet west of milepost "E. St. L. 117, Eldorado 4 M." 62 feet south of center of track, in field of Mrs. Liza Elder, iron post stamped "390 1906" | 390.763 |
| Raleigh, 1.6 miles south of; southeast corner where road turns south, T. 8 S., R. 6 E., corner secs. 21, 22, 27 and 28, iron post stamped "373" | 372.866 |
| Raleigh, 4.28 miles south of; T. 8 S., R. 6 E., middle east and west of sec. 4, 0.33 mile south of township line, southeast of second right angle in road south, iron post stamped "363" | 362.623 |
| Raleigh, 7.41 miles southwest of; southeast of crossroads at Mt. Moriah church, corner between Brushy, Raleigh and Harrisburg. townships, 0.25 mile east, iron post stamped "459 1906" | 459.061 |
| Mt. Moriah, 2.94 miles west of; southwest of crossroads at center of Brushy township, at Voting House, iron post stamped "402 1906" | 401.863 |
| Saline county line, 0.5 mile west of, on east and west road which leads into Attila, iron post stamped "487 1906" | 487.104 |

## USE OF THE STRUCTURAL MAP.

The contour map when used in connection with the topographic map or surface elevations determined by field work, enables one to calculate the depth to coal No. 5 in the areas between test holes, and also indicates steepness of dip by relative closeness of contours to one another. As indicated by the contours the dip of coal No. 5 varies greatly in direction and rate, but in general terms it appears to be northward from the south margin of the area until an irregular belt of dome-like features is reached. This is shown northwest of Harrisburg in section 7 and follows an irregular course to the west margin of the area in section 35, T. 9, R. 4. Along this belt coal No. 5 is folded or faulted up to a position from 100 to 200 feet above its altitude just to the south. Northward the beds descend again in more orderly manner. From the highest to the lowest positions No. 5 descends a total distance of about 425 feet. If the change in altitude be due to dip the rate must be steep in several localities, as shown by dashed contours. The following warrant careful notice and further testing to determine the facts.

*Localities of Pronounced Dip or Faulting.*

| T. | R. | Sec. | Change in Altitude. | | Feet per mile. |
|---|---|---|---|---|---|
| | | | Feet. | Distance (miles.) | |
| 8 | 4 | 34-35 | 150 | ½ | 300 |
| 9 | 4 | 1 | 112 | ⅓ | 336 |
| 9 | 5 | 8 | 132 | ½ | 264 |
| 9 | 5 | 11-12 | 123 | ⅔ | 164 |
| 9 | 6 | 2 | 113 | ¾ | 141 |
| 9 | 6 | 8 | 85 | ¼ | 349 |

Certain conditions within and nearby the area suggest the presence of faults. The considerable changes in altitudes just referred to, when compared to the usual structure here and in the quadrangle to the east appear to be rather local in distribution, and suggest abnormal conditions. Small faults with displacements of 1 to 5 feet occur in several of the mines and furthermore dikes of igneous rock, eight to fourteen feet thick, cut the coal.* The intruded rock is nearly identical in composition to that of Pope and Hardin counties to the south and east, which is related to deposits of fluorspar, lead and zinc. In one of the Saline county dikes a crystal of zinc sulphide, "jack" was found by Mr. Wheeler of the survey. Other evidence of even greater weight is added by the fault which trends westward from Shawneetown in Gallatin county, along the north face of the "Gold Hill" range of hills, and which has a displacement exceeding 1,000 feet about three and one-half miles south of the Eldorado quadrangle. From general evidence this zone of disturbance continues a little south of west, towards Stonefort, and its proximity to this area makes it very probable that minor faults do occur here. They must be of small magnitude and need hardly be considered serious factors in developing the field, unless they prove to be much more numerous than at present indicated.

While the contours show the varying altitude of coal No. 5, the structure of coal No. 7 is not exactly parallel to it, being somewhat more regular in attitude. The position of No. 7 or other beds may be approximately determined from the contours, however, by adding or subtracting a figure corresponding to the average interval which separates No. 5 and the bed sought.

## Coal Resources.

### INTRODUCTION.

The coal of this area is of superior quality and the favorable conditions of its occurrence has so stimulated production during the last few years as to make the region one of great importance. There are seven commercial mines in the area of this report, and a considerably larger number in the immediately adjoining area. Though the accompanying sections (Fig. 19) show coal at over a dozen horizons only two are now worked, Nos. 7 and 5. Practically all of the others have so far proved too thin for competition under present commercial conditions, but there is strong possibility that some of them may prove to be locally of value. It is especially probable that some of the lower coals which are of workable thickness elsewhere in Illinois and indeed reported as much as four feet thick here, may some day be utilized.

### DESCRIPTION OF COALS NOS. 5 AND 7.

#### *Results of Borings.*

A study of borings warrants the statement that the horizons of coals Nos. 5 and 7 underlie nearly all of the area and that one or both have minable thickness in almost every hole drilled.

* Dikes occur in the following mines in or near the area here mapped: O'Gara Coal Co., Nos. 3 and 8; Saline County Coal Co., No. 2; National Mining Co.

The horizon of coal No .7 is absent through pre-glacial erosion in the extreme southeast and southwest corners of the area, beneath the bottom lands. In the southeast the coal is exposed and has been mined for local use. In the southwest the outcrop is revealed by borings which find the place of the coal occupied by glacial clay and sand. The thickness of No. 7 in the 198 holes penetrating its horizon is shown by the accompanying table. If the records are grouped so as to assemble those in which No. 7 measures from 1 to 10, 11 to 20, 21 to 30 inches, etc., it will be noted that 1½ per cent of the records show no coal; 10 per cent report 1 to 40 inches; 73 per cent 41 to 70 inches; and 15 per cent more than this amount. Partings or bone coal are reported in 7 per cent of the borings.

The distribution of coal No. 5 is widespread but its thickness is more variable than No. 7. Preglacial erosion channels do not reach the horizon within this area, but the outcrop occurs in the region just to the south which will be mapped next season. A number of borings show that No. 5 is thin or absent through irregular deposition or through erosion which accompanied or followed shortly after deposition. A further study of such logs is planned in order to determine the reason for this condition and to apply the facts to adjoining areas. In several instances where coal No. 5 was not reached by drilling, a somewhat deeper hole is necessary to demonstrate its absence.

The thickness of No. 5 in the 184 holes which reached its horizon is summarized in the accompanying table. Eight per cent of the records show no coal; in nine per cent it varies from one to forty inches; in fifty-eight per cent it measures from forty-one to seventy inches; and in twenty-five per cent it exceeds this value. The table indicates a tendency of the drillers to report thicknesses in even feet or half feet, rather than as they actually occur. Thus, coal of 48, 50 and 60 inches is more frequently found in the table than thicknesses just more or less than these values.

*Thickness of Coals Nos. 5 and 7 in Borings Penetrating Their Horizons.*

| Thickness, inches. | No. of records Coal No. 7. | No. of records Coal No 5. | Thickness, inches. | No. of records Coal No. 7. | No. of records Coal No. 5. | Thickness, inches. | No. of records Coal No. 7. | No. of records Coal No. 5. | Thickness, inches. | No. of records Coal No. 7. | No. of records Coal No. 5. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 3 | 13 | 25 | | | 50 | 6 | 5 | 75 | | 2 |
| 1 | 1 | | 26 | | | 51 | 1 | 5 | 76 | 1 | 4 |
| 2 | | | 27 | | 1 | 52 | 3 | 5 | 77 | 3 | 5 |
| 3 | | | 28 | | | 53 | 5 | 12 | 78 | 3 | 3 |
| 4 | | | 29 | | | 54 | 10 | 6 | 79 | | |
| 5 | 1 | | 30 | 3 | | 55 | 3 | 2 | 80 | | 2 |
| 6 | | 3 | 31 | | | 56 | 10 | 5 | 81 | | 1 |
| 7 | | | 32 | | 1 | 57 | 4 | 2 | 82 | 2 | 1 |
| 8 | | | 33 | | | 58 | 1 | 8 | 83 | | |
| 9 | | | 34 | | | 59 | 3 | 1 | 84 | 1 | 8 |
| 10 | | | 35 | | | 60 | 19 | 12 | 85 | | 1 |
| 11 | | | 36 | 5 | 3 | 61 | 5 | 1 | 86 | | 1 |
| 12 | 3 | 1 | 37 | | | 62 | 8 | 5 | 87 | | 1 |
| 13 | | | 38 | | 2 | 63 | 3 | 5 | 88 | | 1 |
| 14 | | | 39 | | | 64 | 11 | 5 | 89 | | 1 |
| 15 | | | 40 | 1 | 1 | 65 | 10 | 1 | 90 | | 1 |
| 16 | 1 | 1 | 41 | 1 | 1 | 66 | 16 | 7 | 91 | | |
| 17 | | | 42 | 1 | 3 | 67 | 3 | 2 | 92 | | |
| 18 | 1 | | 43 | | | 68 | 8 | 2 | 93 | | |
| 19 | | | 44 | | | 69 | 2 | 1 | 94 | | |
| 20 | 2 | | 45 | 2 | | 70 | 4 | 1 | 95 | | |
| 21 | | | 46 | 1 | 4 | 71 | 3 | 1 | 96 | | 2 |
| 22 | | | 47 | | | 72 | 9 | 3 | 104 | | 1 |
| 23 | | | 48 | 5 | 7 | 73 | 2 | 3 | 108 | | 1 |
| 24 | 2 | 2 | 49 | 1 | 2 | 74 | 5 | 2 | 120 | | 1 |

The mines of the area with the exception of one are working No. 5 in preference to No. 7, because of better conditions for mining and higher fuel value. No. 7 is nevertheless an excellent coal, having about the same fuel values here as No. 7 in Williamson county and much better than "No. 6" in the Belleville region, its equivalent.

No. 5 where examined in the mines measures from 59 to 87 inches, being nearly uniform in thickness in each mine. It is free from clay bands and has but occasional thin streaks of sulphur. The latter when present are usually from 1-16 to ½ inch thick and are found from 4 to 10 inches from the top. Exceptionally they are as much as 27 inches from the top, and reach 1 inch in thickness. Locally, the top two inches of coal is boney. The coal is of medium hardness and good appearance, and stands handling and transportation very well. Its composition and high fuel value are indicated by the accompanying tables on page 245. The mining conditions of No. 5 are excellent. The roof is a hard gray shale which stays up with little timbering. Its regularity is interrupted by the protrusion of "nigger heads," frequently exceeding 12 inches in diameter. In all of the mines there is a thin draw slate of 2 to 4 inches which drops with the coal, and in several a second slate falls within a few months if left up. The coal has no well developed cleat and is cut easily in all directions. Chain machines have been installed within the last year and practically no coal is now shot off the solid. The coal is screened or partly re-screened and is shipped mostly to the Chicago market.

Coal No. 7 within this area is mined only at Galatia. It is also worked in the region to the east both for shipment and for local use.

and to the southwest for local use. The seam is recognized by its fossiliferous limestone roof and its "blue band" which occurs near the base of the seam. At Galatia the coal varies from 66 to 76 inches in thickness and has a band of fire clay ½ to 1-½ inches thick located from 10 to 28 inches above the floor. Other impurities of the bed include occasional streaks of shale and a boney and "sulphury" streak about 10 inches below the top, which varies up to ½ inch in thickness. While the coal makes a much poorer appearance than No. 5 it is still a good coal as shown by accompanying tables. The installation of a washer and new screens would very probably extend the market of the coal considerably. There is no cleat showing at Galatia and conditions are fairly regular. Pick mining is employed. The roof consists of a gray shale from a few inches to one foot thick which usually separates the coal from a hard blue limestone from 3 to 4 feet thick. Where the shale is thin it falls with the coal. Locally it is entirely absent. The floor is a fairly hard fire clay 3 or more feet thick.

*Mines of the Area.*

| COMPANY. | No. | LOCATION. | | | | No. of bed. | Average thickness. Inches. | Depth to base of coal. Feet. |
|---|---|---|---|---|---|---|---|---|
| | | T. | R. | S. | Map No. | | | |
| Galatia Coal Co | 1 | 8 | 5 | 11 | 1 | 7 | 66 | 365 |
| O'Gara Coal Co | 1 | 9 | 6 | 2 | 1 | 5 | *84 | *122 |
| | 12 | 9 | 6 | 2 | 2 | 5 | 59 | 428 |
| | 2 | 9 | 6 | 15 | 1 | 5 | *66 | 248 |
| | 3 | 9 | 6 | 15 | 2 | 5 | 83 | 239 |
| | 4 | 9 | 6 | 22 | 1 | 5 | 84 | 220 |
| | 9 | 6 | 6 | 21 | 1 | 5 | 87 | 156 |

* Report Bureau of Labor Statistics 1906.

## CHEMICAL ANALYSIS OF THE COALS.

The high quality of the coals of this region is shown by analyses of samples collected by Mr. W. F. Wheeler of the Survey. Each was obtained from a clean face of the coal by cutting a channel from top to bottom and collecting the fragments on oil cloth. After each sample was crushed and quartered down it was placed in an air-tight can before leaving the mine. Analysis was made within a week after sampling. Coal No. 7 was sampled at Galatia and gave the results noted in the following table. Coal No. 5 was found to be so uniform in character between Eldorado, Harrisburg and Carrier Mills that all the results are summarized here though many of the samples came from outside the immediate area of this report, as shown by the following table.

*Sources of Samples of Coal No. 5.*

| | |
|---|---|
| O'Gara Coal Co | 3* |
| O'Gara Coal Co | 8 |
| O'Gara Coal Co | 9* |
| O'Gara Coal Co | 12* |
| O'Gara Coal Co | 14 |
| Wasson Coal Co | 1 |
| Saline County Coal Co | 2 |

*In area of this report.

*Analyses of Coals in Saline County, Ilinois.**

Coal No. 5.—(Seven Samples.)†

| | As Received. | | | Oven Dry. | | | Ash Moisture, and Pyrite Free. | | |
|---|---|---|---|---|---|---|---|---|---|
| | High. | Low. | Average. | High. | Low. | Average. | High. | Low. | Average. |
| Moisture | 6.64 | 4.43 | 5.90 | ........ | ........ | .......... | ........ | ........ | .......... |
| Vol. Matter | 36.20 | 33.48 | 34,69 | 38.52 | 35.66 | 36.88 | ........ | ........ | .......... |
| Fixed Carbon | 52.82 | 47.87 | 50.41 | 55.25 | 50.94 | 53.66 | ........ | ........ | .......... |
| Ash | 10.89 | 7.17 | 8.98 | 11.58 | 7.62 | 9.55 | ........ | ........ | .......... |
| Sulphur | 3.30 | 2.19 | 2.60 | 3.52 | 2.30 | 2.77 | ........ | ........ | .......... |
| B. T. U | 12883 | 12159 | 12552 | 13700 | 12942 | 13197 | 14962 | 14830 | 14910 |

Coal No. 7.—(Galatia Coal Company.)‡

| | As Received. | Oven Dry. | Ash, Moisture, and pyrite free |
|---|---|---|---|
| Moisture | 5.98 | .............. | .............. |
| Vol. Matter | 35.22 | 37.46 | .............. |
| Fixed Carbon | 45.84 | 48.75 | .............. |
| Ash | 12.96 | 13.79 | .............. |
| Sulphur | 3.51 | 3.73 | .............. |
| B. T. U | 11757 | 12505 | 14728 |

* Analyses by W. F. Wheeler and J. M. Lindgren under direction of Prof. S. W. Parr.
† Samples include entire seam except in one mine where one inch pyrite ball was excluded.
‡ Sample excludes 1½ inch blue band.

## Mining Methods.

The mines of the O'Gara Coal Company within the area of this report are equipped with modern automatic dumping cages and shaker screens delivering to three tracks. The coal is undercut by electric machines, and hauled by mules and electric motors. The plants are strictly modern. At Galatia the coal is hand mined, hauled by mules and at the tipple is dumped by hand over bar screens. All of the mines use modifications of the Room and Pillar system.

# Notes on the Belleville-Breese Area.

(By J. A. Udden and F. W. DeWolf.)

## Introduction.

The Belleville region has been an active mining center for many years, and includes some of the largest mines in the State. The area examined during the summer of 1907 is included on the Belleville and Breese topographic maps* prepared by the State Geological Survey and the U. S. Geological Survey in coöperation.

The following preliminary report is based on field work by the senior author, assisted by Mr. I. J. Broman. The chemical notes have been prepared by F. W. DeWolf.

## Stratigraphic Notes.

In the area of the Breese and Belleville quadrangles the coal measures are covered by from 50 to 100 feet of drift, and over the greater part of the country the streams do not cut through this cover. Exposures of the bedrock are limited to a few square rods scattered here and there along the courses of the creeks and ravines, seldom running continuously as much as a quarter of a mile. The conditions are such that a section of the coal measure strata shown in the outcrops can never be constructed from these alone, and for this reason the structure of the region must be made out largely from records of such deep explorations as have been made for coal or for water.

The log of the boring made by the Postel Milling Company at Mascoutah a few years ago penetrated the sedimentary rocks to the depth of 3,070 feet. The rocks of the lower 2,500 feet of this section are older than the coal measures. The main coal at Mascoutah lies at an elevation of 262 feet above the sea and at depths averaging 170 feet below the surface. As there are no indications of any fractures or other dislocations of the bed rock in this region, it is safe to conclude that the section shown in the Mascoutah well represents stratified rocks which underlie this entire area. The coal measures consist principally of clays, shales and sandstone, while the underlying Mississippian (Lower Carboniferous) Devonian, Silurian and Ordovician sediments consist in the main of limestones, which are interbedded with three or four formations of shale.

*Copies may be obtained for five cents each by addressing the Director, U. S. Geological Survey, Washington, D. C.

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## STRUCTURE.

The Belleville or "Number 6" coal, which has been extensively mined in this area, offers data from which the structure may be determined. Its elevation above sea level has been ascertained at about 100 localities, which are fairly well scattered over the area. Most of these elevations have been obtained from mines, and a few are from drillings made especially for the exploration of the coal. Thirty-two of them have been calculated from the outcrop of a limestone, whose position in the section is known. The contour lines shown in the accompanying plate (12) are based upon these data and exhibit graphically the elevation of this coal and hence also the general geological structure of the region. The data appear in the following table:

*Altitude of the Belleville Coal.*

| Map No. | Source of Data. | Altitude above sea level.* |
|---|---|---|
| 1a | Coal mine | 366 |
| 1b | ..do. | 335 |
| 2 | ..do. | 295 |
| 3 | ..do. | 275 |
| 4 | Rock outcrop | 280 |
| 5 | Coal mine | 370 |
| 6 | ..do. | 356 |
| 7 | Water well boring | 331 |
| 8 | ..do. | 330 |
| 9 | Coal mine | 317 |
| 10 | Water well boring | 325 |
| 11 | Coal mine | 335 |
| 12 | ..do. | 349 |
| 13 | Coal test boring | 308 |
| 14 | ..do. | 352 |
| 15 | Rock outcrop | 350 |
| 16 | Coal test boring | 353 |
| 17 | ..do. | 380 |
| 18 | Rock outcrop | 332 |
| 19 | ..do. | 300 |
| 20 | Coal mine | 290 |
| 21 | Rock outcrop | 320 |
| 22 | Coal mine | 330 |
| 23 | ..do. | 350 |
| 24 | ..do. | 355 |
| 25 | ..do. | 345 |
| 26 | ..do. | 340 |
| 27 | ..do. | 344 |
| 28 | ..do. | 350 |
| 29 | ..do. | 348 |
| 30 | ..do. | 345 |
| 31 | ..do. | 370 |
| 32 | ..do. | 375 |
| 33 | ..do. | 380 |
| 34 | ..do. | 395 |
| 35 | ..do. | 431 |
| 36 | Water well boring | 395 |
| 37 | Coal mine | 450 |
| 39 | ..do. | 440 |
| 39 | Air shaft | 424 |
| 40 | Water well boring | 430 |
| 41 | Coal mine | 390 |
| 42 | ..do. | 397 |
| 43 | ..do. | 380 |
| 44 | Gas well boring | 408 |
| 45 | Coal mine | 382 |
| 46 | ..do. | 350 |
| 47 | ..do. | 340 |
| 48 | ..do. | 325 |
| 49 | ..do. | 262 |
| 50 | ..do. | 128 |

*Altitude of Belleville Coal.*—Concluded.

| Map No. | Source of Data. | Altitude above sea level.* |
|---|---|---|
| 51 | Water well boring | 128 |
| 52 | Rock outcrop | 112 |
| 53 | Water well boring | 120 |
| 54 | Rock outcrop | 127 |
| 55 | Coal mine | 126 |
| 56 | Rock outrop | 122 |
| 57 | ..do | 142 |
| 58 | ..do | 147 |
| 58 | Coal mine | 160 |
| 60 | Rock outcrop | 152 |
| 61 | Coal mine | 169 |
| 62 | ..do | 174 |
| 63 | ..do | 200 |
| 64 | ..do | 195 |
| 65 | Water well boring | 218 |
| 66 | Coal mine | 244 |
| 67 | Water well boring | 260 |
| 68 | Coal test boring | 180 |
| 69 | Rock outcrop | 162 |
| 70 | Water well boring | 152 |
| 71 | Rock outcrop | 172 |
| 72 | ..do | 192 |
| 73 | ..do | 187 |
| 74 | ..do | 192 |
| 75 | ..do | 202 |
| 76 | ..do | 192 |
| 77 | Water well boring | 180 |
| 78 | Rock outcrop | 110 |
| 79 | ..do | 105 |
| 80 | ..do | 100 |
| 81 | ..do | 80 |
| 82 | ..do | 90 |
| 83 | ..do | 90 |
| 84 | ..do | 105 |
| 85 | ..do | 80 |
| 86 | ..do | 70 |
| 87 | ..do | 80 |
| 88 | ..do | 65 |
| 89 | ..do | 75 |
| 90 | ..do | 70 |
| 91 | ..do | 60 |
| 92 | Coal mine | 55 |
| 93 | ..do | 37 |
| 94 | ..do | 53 |
| 95 | Coal test boring | 50 |
| 96 | ..do | 72 |
| 97 | Coal mine | 62 |

*Determined in close approximation by hand level, barometer, or estimate from topographic map.

It will be seen that there is a general dip from west to east of about twelve and one-half feet to the mile. This is slightly more than the increase of the depth to the coal from the surface, measured in the same direction, owing to the fact that the land has an average elevation of about twenty-five feet more on the west side of the Belleville sheet than it has on the east side of the Breese sheet. This difference in the elevation of the land is partly due to the greater thickness of the drift in the west.

The dip is most regular along the north side of the area. It will be noticed that the distance between the contour lines is here quite uniform. The general descent is a trifle less than eleven feet to the mile, while measured on the south side of the map it amounts to fully fourteen feet. The southwest corner of the area has been elevated a little

more than the northwest corner. The general dip to the east is greatest in the country between Mascoutah and New Balden, where it exceeds twenty feet to the mile, and least in the country between New Baden and Germantown, where it is only a trifle more than six feet to the mile.

The general monoclinal structure is affected by some minor deformations, the most important of which is an anticlinal fold whose crest follows a line from a point about a mile east of Belleville to a point about a half mile west of O'Fallon and descends also in the same direction. It is a very flat anticline, whose average height probably does not exceed twenty feet, although it measures at least four or five miles in width. It causes an irregular bend in the 400-foot contour line and in the 350-foot contour line it produces a loop six miles long north of O'Fallon. In the 300-foot contour it is hardly perceptible, but it is possible that this may be due to the scarcity of the data at hand. A shallow syncline is indicated northwest of the anticline by the low attitude of the coal east of Collinsville. The coal in Caseyville township lies at a level, with hardly any perceptible dip in any direction. Perhaps this tract should be regarded as the west limb of the Belleville-O'Fallon anticline. It is believed that this fold is a part of a more extensive uplift which occurs in the country to the southwest of Belleville.

There is another class of still smaller deformations which are very generally met with in the mines. These consist in dips that may run on for a few rods to half a mile and then change in the opposite direction. It may be that these also are due to folds with a definite trend, but such observations as have been made on them do not indicate much regularity. These dips may amount to as much as 50 feet in a mile, but they usually do not persist so far. They seem to be more common in the mines in the vicinity of Belleville than elsewhere.

Some small faults occur in the New Baden and the West Trenton mines. In the former some have been followed for nearly a mile. They appear on the mine map as irregular fractures trending variously from east-west to nearly northwest-southeast and splitting at several points. The greatest displacement which was observed in the faults in this mine does not exceed six feet. The down-throw is to the north, and the hade of the faults varies from 45 to 60 degrees to the north. The faulted blocks have a slight tilt to the south, the faults thus being of the normal type.

A somewhat similar dislocation was noted in an exposure in the bottom of the creek running through the south half of section 28 in O'Fallon township. It consisted of three small fault planes, from two to four feet apart, with thin dislocated blocks between, and trending from east to west. The total displacement could only be a few feet. Some small faults were also noted in one of the mines at Glen Carbon. When close together such faults sometimes affect the coal to such extent that they interfere with its safe mining. Such is not the case in any of the mines in this area.

## Coal Resources.

While the mines of the Belleville-Breese quadrangle lie mostly in St. Clair county, a considerable number of the large producers are situated also in Madison and Clinton counties. The rapid increase of production of these counties is due in considerable part to the growing output of the area here described. In this connection the following figures from the report of the U. S. Geological Survey are of interest:

*Increase in Coal Production.*

| Counties. | Production in short tons | |
|---|---|---|
| | 1906 | 1907 |
| Clinton | 515,796 | 1,302,391 |
| Madison | 3,651,296 | 4,254,160 |
| St. Clair | 4,578,372 | 4,511,879 |

*Partial Table of Mines.**

| Name or owner. | Class. | Map No. |
|---|---|---|
| Abbey | Local | 6 |
| Beatty Brothers | Commercial | 48 |
| Beatty | Local | 49 |
| Belleville and O'Fallon Coal Co | Commercial | 34 |
| Bond | Abandoned | 23 |
| Brauch, John | Local | 37 |
| Breese-Trenton Mining Co | Commercial | 62 |
| Breese-Trenton Mining Co | ..do | 93 |
| Cluley-Miller Coal Co. (Ruby) | ..do | 28 |
| Consolidated Coal Company | ..do | 3 |
| Consolidated Coal Company | ..do | 12 |
| Consolidated Coal Company | ..do | 92 |
| Co-operative Coal Co | ..do | 94 |
| Donk Brothers Coal and Coke Co. No. 3 | ..do | 2 |
| Donk Brothers Coal and Coke Co. No. 1 | ..do | 5 |
| Donk Brothers Coal and Coke Co. No. 2 | ..do | 1b |
| Enterprise Coal company | ..do | 47 |
| Fullerton Coal Company | ..do | 33 |
| Glendale Coal and Mining Co. Airshaft | | 40 |
| Glendale Coal and Mining Co | Abandoned | 41 |
| Heintz Bluff | ..do | 9 |
| Highland Coal Company | Commercial | 42 |
| International Coal and Mining Co. (Bennett) | ..do | 20 |
| International Coal and Mining Co. (Carbon) | ..do | 24 |
| Lebanon City Coal Co | Local | 66 |
| Lumaghi Coal Co. No. 3 | Commercial | 11 |
| Madison Coal Co. No. 2 | ..do | 1a |
| Phul, Herman | ..do | 38 |
| Prairie Coal Company | ..do | 30 |
| Silver Creek Coal and Mining Co. (Yoch mine) | Abandoned | 22 |
| Southern Coal and Mining Co. No. 6 | Commercial | 45 |
| Southern Coal and Mining Co. No. 8 | ..do | 46 |
| Southern Coal and Mining Co. New Baden | ..do | 50 |
| Southern Coal and Mining Co. Germantown | ..do | 97 |
| St. Louis & O'Fallon Coal Co. No. 2 | ..do | 31 |
| Summit Coal and Mining Co | ..do | 32 |
| Joseph Taylor Coal Co | ..do | 25 |
| Joseph Taylor Coal Co | ..do | 27 |
| Joseph Taylor Coal Co | ..do | 29 |
| Tower Grove Coal Co | Local | 43 |
| Trenton Coal Co | Commercial | 61 |
| Vinegar Hollow | Abandoned | 26 |
| White and Nesbit | Commercial | 35 |
| George Widicus | Abandoned | 64 |
| Julius Winkler | ..do | 63 |
| | ..do | 39 |
| | ..do | 59 |
| | ..do | 55 |

* Includes only mines where data were obtained for the structural map.

Without presenting the evidence at this time it may be stated that there is very little doubt that all the coal mined on the area shown on the map belongs to one and the same seam, and that this seam underlies nearly the entire area with a workable thickness. At Highland it is reported to be absent in a drilling which was made many years ago. This must be considered as local, since the coal is known to exist in all directions around Highland. At Aviston it was found too thin for profitable working, and at Germantown the seam is thinner than in any other mine in this region. Data are too few to justify generalization as yet, but the fact that these three places arrange themselves in a line suggests a change in the coal seam due to some linear geo-

graphical feature at the time the coal was made. In the light of our present knowledge there is not a section of land in this whole area on which it would seem out of place to explore for coal. Of course there are localities of probably small extent, where the coal either was thin when originally laid down, or where it perhaps suffered from contemporaneous erosion and concomitant small faulting which reduced and broke up the seam sufficiently to render mining of these small areas unprofitable under present economic conditions.

The question of the existence of a workable seam some 40 or 50 feet under the Belleville coal must be left undecided for the present. That there is another coal at this horizon is evident from some of the drillings and explorations in the southern part of this area and at Mascoutah, but it is also clear that this lower seam is not as regular in its development as the Belleville coal. Very likely there are places where it is thick enough for profitable mining. The explorations in the north part of the region show that this coal is either thin or absent.

## Chemical Analyses of the Coals.

The chemical character of the "Belleville" seam was investigated by analysis of a number of samples collected by Mr. W. F. Wheeler, of the Survey, and Mr. Tom Moses, State Mine Inspector. Each sample was cut from top to bottom of a fresh face, collected on oil-cloth, crushed, quartered down and sealed immediately. Impurities which are said to be excluded in shipping coal, have in past sampling of the Survey been excluded from the face sample. As it has been found impossible, however, to duplicate the exact custom of loaders and pickers, this variable has been eliminated from present samples by arbitrarily excluding impurities measuring ⅜ inch or more in thickness. Samples were taken from the mines of the following list:

| Company. | Mine Name or Number. |
|---|---|
| Breese Trenton Mining Co | Breese |
| Cluley Miller Coal Company | Ruby |
| Consolidated Coal Co | Breese |
| Consolidated Coal Co | 17 |
| Coöperative Coal and Mining Co | 1 |
| Donk Brothers Coal and Coke Co | 1 |
| Donk Brothers Coal and Coke Co | 2 |
| Donk Brothers Coal and Coke Co | 3 |
| Fullerton Coal Co | Belleville |
| International Coal and Mining Co | Bennett |
| International Coal and Mining Co | Carbon |
| Lebanon City Coal Co | 1 |
| Lumaghi Coal Co | 2 |
| Pittsburg Mining Co | Belleville |
| St. Louis & O'Fallon Coal Co | 2 |
| Southern Coal Co | New Baden |
| Southern Coal Co | Shiloh |
| Southern Coal Co | Germantown |
| Joseph Taylor Coal Co | St. Ellen |
| Trenton Coal Co | Breese |

While the coal mined in this area is doubtless all from the same bed its physical and chemical characters vary considerably from place to place. The data collected will result in some interesting conclusions later, but at this time only general observations are presented. In the following tables the analyses of coal "as received" most closely approximate the actual commercial production of the area, though there is doubtless some differences as regards moisture and ash. Certain variations in the analyses seem related to differences in roof materials of the coal beds. About one-third of the mines of the above list have a shale roof while the others have a hard limestone within a few inches or feet. In coal "as received" from the mines with shale roof the moisture in general runs higher and the heat values lower than from the other class, though this condition has exceptions. On the basis of "ash, moisture, sulphur free" coal the B. t. u. values of the coal from under shale roof averages 14275 per pound as compared with 14570 for the other samples, and this general tendency has no exception, although the explanation of the fact has not yet been reached.

*Analyses of 21 Samples from Belleville, Breese Quadrangles, Illinois.*

| | As Received. | | | Oven Dry. | | | Ash, Moisture, Sulphur, Free. | | |
|---|---|---|---|---|---|---|---|---|---|
| | High. | Low. | Average | High. | Low. | Average | High. | Low. | Average |
| Moisture | 15.91 | 9.41 | 12.30 | ...... | ...... | ...... | ...... | ...... | ...... |
| *Vol. matter | 40.80 | 29.95 | 35.92 | 45.05 | 34.72 | 40.94 | ...... | ...... | ...... |
| *Fixed carbon | 45.50 | 37.43 | 40.68 | 52.75 | 42.91 | 46.46 | ...... | ...... | ...... |
| Ash | 14.26 | 9.33 | 10.84 | 16.56 | 9.69 | 11.72 | ...... | ...... | ...... |
| Sulphur | 4.59 | 1.39 | 3,55 | 5.29 | 1.65 | 4.04 | ...... | ...... | ...... |
| B. t. u. | 11,523 | 9,916 | 10,965 | 12,982 | 11,639 | 12,500 | 14,885 | 14,174 | 14,500 |

* Determined only for 18 samples.

*Analyses of Best (1) and Poorest (2) Samples, Based on B. t. u. as Received.*

| | As Received. | | Oven Dry. | | Ash, Moisture, Sulphur, Free. | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 1 | 2 |
| Moisture | 9.44 | 14.81 | ...... | ...... | ...... | ...... |
| Vol. matter | 40.80 | 30.87 | 45.05 | 36.24 | ...... | ...... |
| Fixed carbon | 39.59 | 40.21 | 43.72 | 47.20 | ...... | ...... |
| Ash | 10.17 | 14.11 | 11.23 | 16.56 | ...... | ...... |
| Sulphur | 3.96 | 2.55 | 4.37 | 2.99 | ...... | ...... |
| B. t. u. | 11,523 | 9,916 | 12.723 | 11,639 | 14,582 | 14,174 |

# Defects in Coal Number Five at Peoria.

(By J. A. Udden.*)

## Contents.



*The author is under great obligations to Mr. James Taylor of Peoria, State Mine Inspector, for valuable assistance in the field and for aid in securing information that no one less acquainted with the field and with the local mining conditions could have obtained.

## INTRODUCTION.

The principal coal seam in the vicinity of Peoria is known as coal No. 5 of the Illinois coal field.* To the west of Illinois river this lies at an elevation of 475 feet above sea level, and back of the bluffs on the east side of the river in Tazewell county, it has an elevation of 455 feet. On a line running from north-northwest to east-southeast it dips four feet to the mile in the latter direction. This is the general attitude of the bed as ascertained by averaging some 60 observations. Local dips are often much greater. Within a radius of ten miles from Peoria the extreme difference in elevation of the seam is nearly 100 feet.

Before the excavation of the valley of the Illinois river this seam was continuous, and it occupied, roughly speaking, the level of the surface of the present bottom lands, rising above this to the north and west and dipping below it to the south and east.

Disregarding erosion by the present drainage the thickness of the cover over the seam on the west side of the river ranges from 100 to 200 feet. Away from the river, probably three-fourths of this cover consists of coal measure sediments. Nearer to the main drainage channels the thickness of the drift increases and may make the greater part of the cover. In Tazewell county this is mostly the case, and over much of the land there, the coal was already removed before the drift was deposited. In the Peoria region preglacial erosion had just begun to cut into this coal seam, when the great ice age began.

## "WASH."

It is to be expected that the working of a coal so situated should have sometimes proved unprofitable. In the mines in Tazewell county the entries have on several occasions come to the edge of the coal and have led out against the drift filling. The same has happened in the operations at Edwards and at Krum, on Kickapoo creek. Miners recognize that these defects in the coal are due to erosion and speak of the drift as "wash." It frequently consists of sand and silt, which in some instances has been found to contain imbedded trunks of trees and other vegetation. Experience has shown that the surface of the coal measures does not always conform to the present topography of the land, and operators are careful to avoid unprofitable explorations in places where "wash" has been encountered.

*Worthen's numbers of the several coals in the Illinois field are used in this paper. Coal number 6 lies at about 70 feet above coal number 5, and coal number 7 lies about 45 feet above number 6, in the territory here discussed. The lowermost of these three seams is the only one now worked.

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## GLACIAL FRACTURES.

### LIST OF LOCALITIES.

There are some peculiar fractures which affect this coal in the vicinity of Peoria, and these have proved a serious cause of unprofitable work in this region. These fractures have been encountered in several mines that are no longer in operation.* Below is a list of the locations of these mines. It is based on information furnished by Mr. Richard Newsam, Mr. Isaac Wantling and some other operators of long experience:

*List of Localities where Fractures have been Encountered, Affecting Coal Number 5 in the Peoria Quadrangle.*

1. In Shoal's old mine in section 1, T. 7 N., R. 7 E., about 1,500 feet west of the river bluffs.
2. In the southeast quarter of section 2, T. 7 N., R. 7 E.
3. In the east half of the southwest quarter of section 11, T. 7 N., R. 7 E.
4. In the west half of the nortwest quarter of section 14, T. 7 N., R. 7 E.
5. In the west half of the northeast quarter of section 19, T. 7 N., R. 7 E.
6. In the east half of the northwest quarter of section 19, T. 7 N., R. 7 E., about 600 feet north of the tracks of the T., P. & W railroad.
7. In the northeast quarter of section 21, T. 7 N., R. 7 E., about 600 feet north from the face of the river bluffs.
8. In the northeast quarter of section 2, T. 8 N., R. 7 E.
9. Near the north line of section 12, T. 8 N., R. 7 E., about 400 feet west from the west bluff of Kickapoo creek.
10. In the southwest quarter of section 6, T. 25 N., R. 4 W. (Tazewell county.)
11. About one-sixth mile west from the center of section 19, T. 25 N., R. 4 W. (Tazewell county.)

In borings which have been made by churn drills to explore for coal, the absence of the coal at its usual level has been noted at a few points, and it is believed that some irregularities in the structure of the coal measures have been indicated in some of these places. No coal was encountered in a boring in the west half of the southwest quarter of section 10, T. 7 N., R. 7 E. The same was the case in two holes bored in the east half of the same quarter of the same section, and in two holes in the northeast quarter of section 15 in the same township and range.

### EXPOSURES IN MINES.

*The German Coal Company's Mine.* The only place where these disturbances have been recently explored in mining operations is in the workings of the German Coal Company. The main entry of these mines is in the base of the bluff near the southeast corner of section 2 in Hollis township. It bears at first about 23° west of north, but farther in it turns more to the northwest. Some 200 yards from the entrance the country rock was seen to dip 15° to the northwest in the walls of the entry. About thirty yards farther in a fault-like fracture

*See paper by Richard Newsam: *A Fault in Peoria County*, published in the Journal of the Illinois Mining Institute, Vol. 1, No. 3, pp. 271-273.

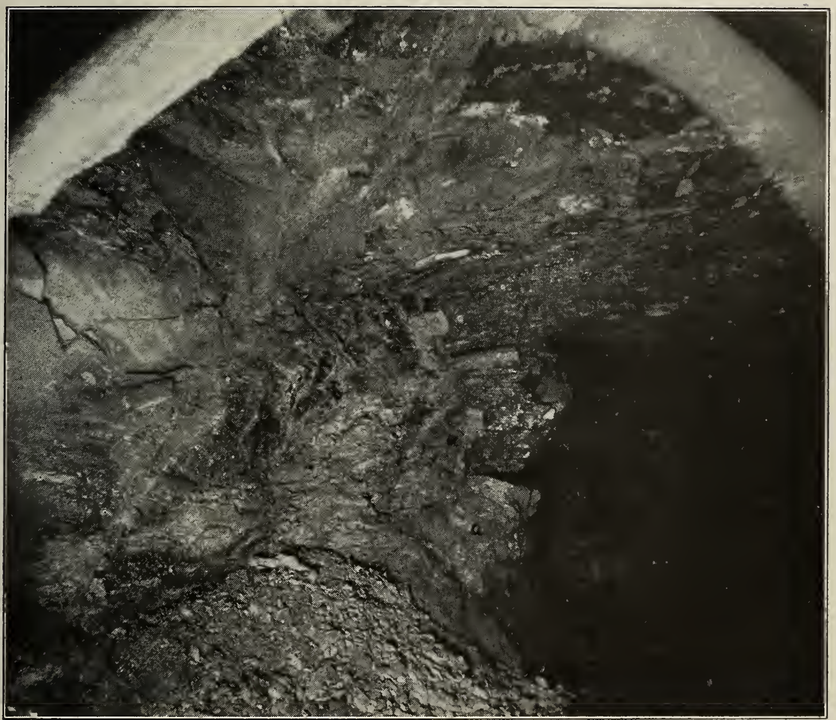
bearing north and south brings the coal up to the full height of the entry. (Fig. 20 and Pl. 13a.) The coal lies at this level for about sixty yards from this point and then a dip to the north again carries it below the main entry (Pl. 13b), which for the next sixty yards is cut through a sandstone. Then the coal is brought up by a fracture hading 24° to the southeast (Pl. 13c). This block of the coal seam has a thickness of ten feet. In less than eight yards this seam and the strata in which it lies are cut by another fracture having the same trend, but hading to the northwest (Pl. 13d and Pl. 14). The coal here abuts against a wall of argillaceous shale and a partly crushed flange of the upper part of the seam has been pushed in above the shale, and this flange disappears above the roof (Pl. 14). This shaly sandstone first lies in a nearly horizontal position, forming both walls of the entry, but some sixty yards farther in it is affected by a flexure which has broken in the manner of a thrust fault (Pl. 13e). This hades with a low angle to the northwest. About eight yards beyond this another fracture, also clearly a thrust fracture, brings the coal to the full height of the entry (Pl. 13f). This fracture trends about 15° east of north and hades with a high angle to the east (Pl. 15). The coal seam is here double and has been crumpled in a small sharp fold against the fracture. The coal at this point consists of two seams, one above the other, and the two are separated by from a few inches to two feet of clay. Most of the coal taken out was brecciated and broken to such a degree that it was readily worked with a pick and shovel. The miners speak of this as "soft coal." Both seams otherwise resemble the main coal (Worthen's No. 5) in this region and one is forced to the conclusion that the upper seam is the same as the lower; that one part of this coal seam has been pushed over another. The overthrust extends for about thirty yards along the entry. The west side of the double coal terminates abruptly with a nearly vertical fracture that is followed by a fissured and brecciated zone (Pl. 13g). In the southwest wall of the entry the principal plane of motion here follows a sigmoid course in the vertical plane, secondary fissures joining it near its sinuosities at various angles (Pl. 16, a, b, c). The northeast face shows several somewhat parallel and flexous fissures following the main fracture plane which terminates the coal. This fracture plane exhibits indistinct scorings and gougings which run horizontally in both walls. (Pl. 17a, and Pl. 16a.) In fact, the flexuosities of nearly all the fissures in the vertical plane represent horizontal flutings on the blocks separated by these fissures. (Pl. 17b.) It is clear that no vertical movement could have produced such fluting but that the movement producing the dislocation must have been principally in a horizontal direction. The accompanying brecciation is clearly a result of the same movements.

The block on the west side of this plane of displacement consists of strata that overlie the coal in the undisturbed section. It continues for about thirty feet along the entry, its bottom first dipping and then rising, trough-like. The lower part is a strong sandstone which terminates to the west in a rounded edge. The lower side of this sandstone appears to have been ground away below, so as to thin out in

Roof and southwest wall of entry at point d (Pl. 13), looking southeast. A projecting flange of coal is seen in the center of the photograph rising in the roof over the timbers. Several shearing joints show indistinct horizontal striae.

Southwest wall of mine at f. (Pl. 13) looking southwest. A fracture runs across the view with sandstone at the left and coal on the right. Near the sandstone the coal is shattered and mixed with fragments of shale and sandstone.

Southwest wall of main entry at g (Pl. 13), looking southwest. An S-bent shearing plane occurs along a, b, c. Somewhat irregular, indistinct, horizontal flutings occur at a.



Northeast wall of main entry at g, section A and at k, section B. (Pl. 13), looking northeast. The fractured face of the coal appears above and to the left of the receding entry. Horizontal flutings appear on the face of the coal at a. An S-bent belt of fissured coal and shale separates the coal from the sandstone at the left.


Northeast wall of main entry opposite h, section A. (Pl. 13), looking northeast. *a.* Dark shale with streaks of coal, somewhat shattered, possibly the same at b. *b.* Roof shale over coal No. 5. *c.* Coal number 5. *d.* Sandstone.

both directions. (Pl. 13h and Pl. 18.) Such wear could not have been the result of any other movement but one in a horizontal direction. From under this wedge of sandstone the coal again rises. The edge of the wedge has divided the roof shale, part of which continues under the sandstone and part above. (Pl. 18, a, b.) Or it may be that the shale is repeated, and that there is a nearly horizontal thrust fissure following the upper surface of the sandstone. The evidence is not quite clear.

A few feet beyond this point the coal for a short distance measured twelve feet in thickness, and it shows vertical flexuous fissures which trend in a general north and south direction. (Pl. 13i.) All this coal appears to belong to one seam. It is thickened by lateral pressure. In a short distance the vein thins out to the usual dimension of from four and a half to five feet. As far as explored in this direction it has been found to be quite undisturbed, barring some small faults or "slips" involving displacements of from one to three feet. (Pl. 13j.) Two other displacements have also been encountered recently, bad enough to discourage work, but the explorations stopped short of exposing them sufficiently for accurate description.

The general observation is pertinent that the trend of the fractures, as here exposed, varies considerably, from N.-S. to N. 15° E.

*The Pottstown Mine.* The most extensive underground explorations of these faults were made in the old Pottstown mine on the northeast quarter of section 2 in Limestone township. This mine has been abandoned for some time and the workings are now filled with water.

From the descriptions given by the operators it is quite evident that the disturbances in this mine are closely related to those seen in the German Coal Company's working. A memory sketch of the entries and the "faults," which was furnished by one of the miners (Fig 20) indicates that a straight and narrow strip of sandstone lay between the edges to two blocks containing the coal. (Fig. 20a.) This "fault"* ran a course from northwest to southwest.

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*The present authors choose to adopt the new term *fractures* for the dislocations here described. Being, as it is believed, the result of physical processes altogether different from those causing faults, it is desirable that they be known by another term. In appearance they have often a close resemblance to true faults. But the direction of the dislocation is normally horizontal instead of normally vertical. Among the miners in the Peoria region the term "fault" has been applied to these structures, but in a sense wholly different from the usual one. It has been used to designate a part of the ground where the coal is absent, or where it is out of its proper place. The entries are thus said to be driven so and so many feet through the "fault" *i. e.,* through ground where the coal is absent, or where it has been "twisted out of place."

Another straight fracture trending in the same direction cut the coal out on the southwest. (Fig. 20b.) Other fractures with more or less vertical displacement ran transversely to these. In the sketch some

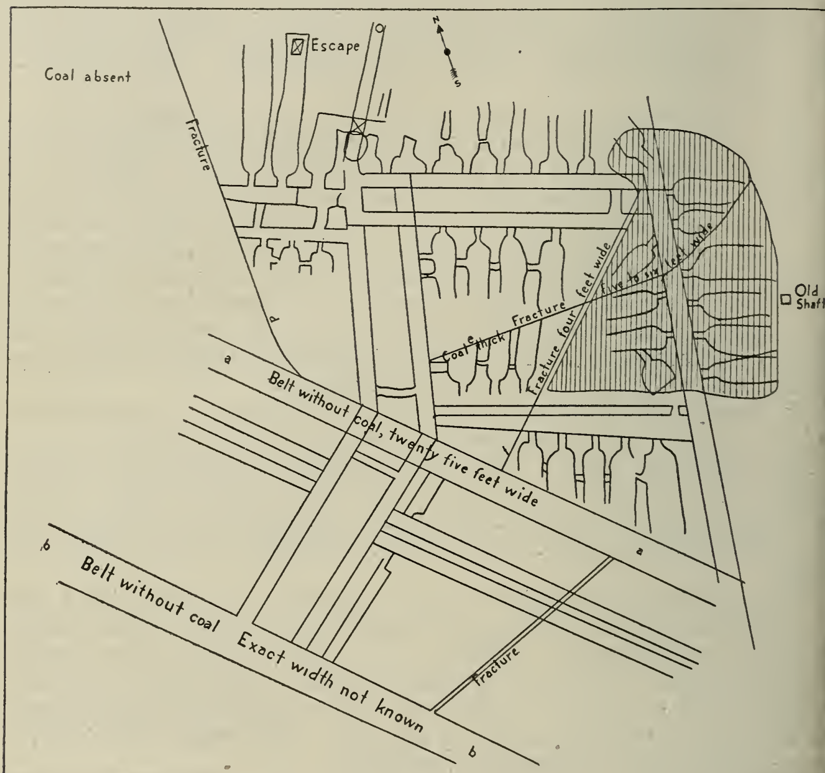



FIG. 20. Sketch from memory, of the faults in the Pottstown mine. The shaded area shows the part of the mine where the coal was double in thickness.

of these show gentle curves near their intersections with other fractures, but are otherwise represented by straight lines. (Fig. 20, c, d, e, f.) Their location was in nearly every case made out in several successive entries and there is no reason to doubt that they were essentially straight, as represented in this sketch.

At least in one instance the coal in this mine increased in thickness on the approach to one of these fractures (Fig. 20e) as if thickened by yielding to lateral pressure. In places the coal was crushed and brecciated. In a part of the mine there were two coals, both of which were mined. They were separated by from one to fifteen feet of shale, sandstone, etc. The west limit of the upper seam followed one of the fracture lines. (Fig. 20b.) This upper seam was known by the miners as the "top coal." It lacked the middle clay seam, which everywhere characterizes the overlying coal number 6 in this region. In one place, near a principal fracture, the coal is reported to have been

repeated twice so that there were three seams separated by several feet of fissured and brecciated material. The middle coal was tilted at a high angle and soon run out.

*The Vickery Mine*—In the Vickery mine, which is on the southwest quarter of section 1, T. 8 N., R. 7 E., and hence lies to the southeast of the old Pottstown mine, a fractured belt has been encountered which is not far from 300 feet in width. The coal is described as terminating more or less abruptly on the sides of the belt, and the opinion of the miners, who believe that this is a continuation of one of the dislocations in the Pottstown mine, is no doubt correct. It trends from northwest to southeast, diagonally across the quarter section.

## SURFACES EXPOSED.

*Minor Disturbances*—Some exposures are found which exhibit disturbances that were no doubt produced by the same causes as the fractures just described. The most common of these consist in a crushed or slightly crumpled appearance of the shales and sandstones which overlie the coal. The stratification of the sediments is shattered, so that it is difficult or impossible to follow any particular parting or seam on the surface of the exposure. This is often associated with some faulting, involving dislocations of small extent, from a fracture of an inch to a foot or two. (Fig. 21.) These faults are perhaps as

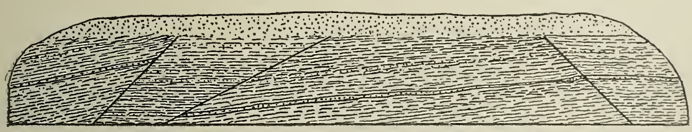


FIG. 21. Thrust fractures in creek bank (n. e. qr. Sec. 2, T. 8 N., R. 7 E.) near Pottstown mine.

frequently reversed as normal, and hade at angles varying from the horizontal to the vertical. Quite often they have opened slightly and and filled with concretionary calcareous material. They may divide and branch in various directions. Usually some flexure of the beds is apparent in such places. This may be quite gentle and run on for one

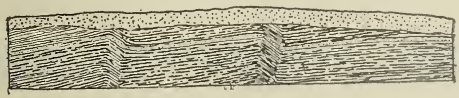


FIG. 22. Folds in shale, E. ½ S. W. ¼, Sec. 2, T. 7 N., R. 7 E.

or two hundred feet, or it may present small and abrupt folds, only a foot or two in horizontal extent (Fig. 22). In sandstones there may be a coarse brecciation, as it were, where blocks from five to fifty feet in diameter have been turned and tilted in irregular fashion (Fig. 23).

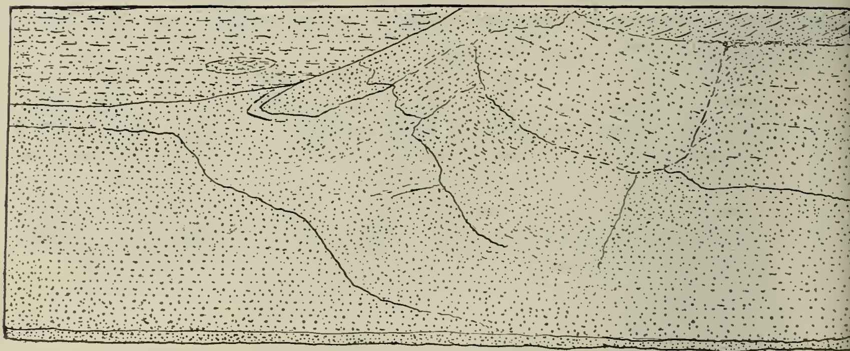


FIG. 23 Fractured sandstone in bank of creek about ⅓ mile south from center of north line of Sec. 4, T. 25 N., R. 4 W. Tazewell county.

*Plications.* At four points violent crumpling and faulting were observed, clearly due to lateral pressure. Two of these places are seen in the banks of a creek which runs from northeast to southwest, through section 27 in Limestone township. Near the mouth of a tributary coming from the south into this creek, plications appear in dark

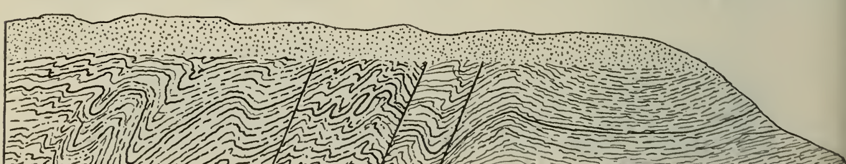


FIG. 24. Plications in left bank of a stream near center of Sec. 27, T. 8 N., R. 7 E.

shales in the left bank (Fig. 24). The trend of the folds is NNW-SSE. The largest fold measured two feet vertically and the clear exposure extended only some fifteen feet in the bank. Three faulted fissures also cut these folded shales, paralleling the folds. Some three hundred yards farther up in the main creek, more folding and faulted fissures were noted in the low right bank of the stream, extending at

FIG. 25. Plications and fracturings 300 yards northeast of those shown in fig. 24.

least thirty feet (Fig. 25). The shales here probably lie above coal number 6 in the general section of the region, and the limestone lying over this coal appears to the west of the lowermost exposure.

Another place showing this folding is in the banks of the creek coming into Little Lamarsh creek, from the northeast at Reed City, in the north half of section 19, Hollis township. The exposures covered only

a few square yards and no definite details could be made out. The disturbances here affect the slate and shale capping coal number 5. A quite plain case of this folding was noted in the south bank of Lick creek near the centre of the northeast quarter of section 29 in Grove-

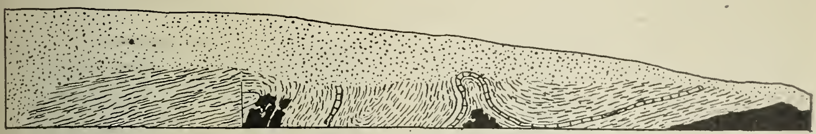


FIG. 26. Crumplings affecting Coal No. 7, near center of N. E. qr., Sec. 29, T. 25 N., R. 4 W., North fork of Lick Creek.

land township in Tazewell county (Fig. 26). This folds coal number 7 and the beds which cap this coal, including a thin seam of dark and impure limestone. The coal and the limestone have broken in some places, but the shales are crumpled into smooth folds which trend in a north and south direction.

*An Inverted Block*—About one fourth of a mile north of Pottstown the left bank of the Kickapoo exposes the fire clay and the shales which underlie coal number 5. Only the lower part of the coal remains, and under this is the fire clay and the shale with a thin seam of coaly shale and two concretionary bands. Fourteen or fifteen feet of the usual succession of the beds appear undisturbed in the bank below the coal. But the north end of this bank is bevelled off and covered by some strata that dip at a high angle (Fig. 27). On a close examina-

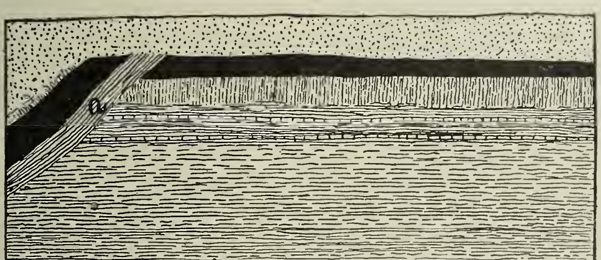


FIG. 27. An inverted block of coal measures on Kickapoo creek, a short distance north of Pottstown. *a.* Roof shale of coal No. 5 which overlies.

tion it appeared that the bevelling was slightly concave and that the overlaying stratum consisted of coal seam number 5, inverted and resting on its capping slate. This block was too large and soft to have been placed in its present position by water or by the ice of the stream. It was closely pressed against the horizontal beds and it appeared as a part of the bed rock. It is believed that this is a dislocation like those found in the Pottstown mines.

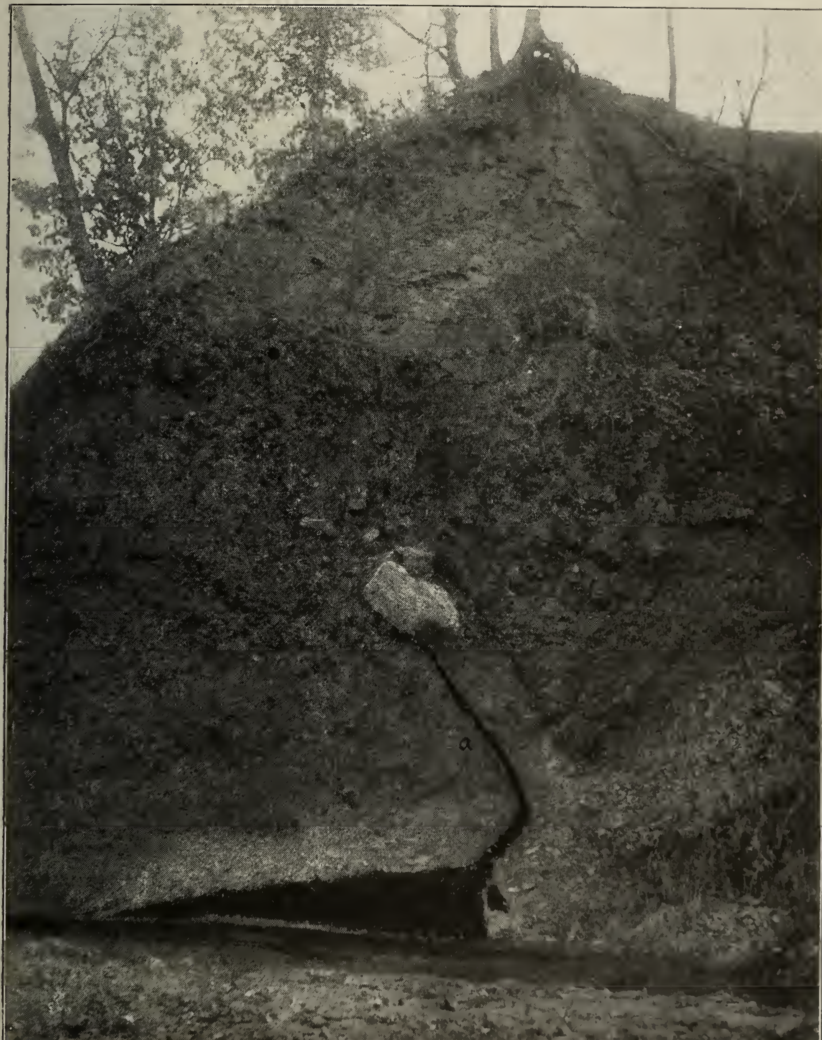
*The Lamarsh Creek Fractures*—The most instructive surface exposure of these disturbances was found in the right bank of Lamarsh creek near the center of section 10 in Hollis township. It is at a point

where the stream has exposed the north side of a projecting spur of the upland, some hundred yards below the mouth of a small tributary which joins the creek from the west. About twenty feet of coal measure strata are overlain by assorted drift, consisting of clayey gravel, sand and silt (Pl. 19). The east end of the exposure shows the sandy shales overlying coal number 5, dipping from 5° to 20° to the southeast. The stratification presents a slightly shattered appearance. Following the bank northwestward the coal comes up, rising about two feet above the water in the creek. It then terminates abruptly against a fault-like fracture which trends north 15° west. This fracture extends up through the coal measures to the drift (Plate 19, a). A stringer of broken coal follows it from the upper edge of the coal seam to the lower side of a limestone boulder which projects downward from the drift into the shale. It is paralleled by another fracture, three feet to the west (Plate 19 b ). This is so sharply cut that it may in places be traced with the edge of a knife. Both fractures bend in a vertical plane so as to present convexities to the west. The west fracture cuts the shales about six inches away from the limestone boulder and can be traced about as far up as to the upper edge of this boulder. The contact between the bed rock and the drift in the whole exposure is at a level just above this boulder. Another small and sharply marked shearing plane runs diagonally across the block between the two main fractures in such a way as to inclose a triangular area on the surface of the exposure under the limestone boulder, between itself and the east fracture (Pl. 19c). In the lower apex of this triangle some drift pebbles were noted. Some such pebbles and also some rounded lumps of boulder clay were found in the lower part of the west fracture. From this it is evident that the fracturing has occurred at a time contemporaneous with, or subsequent to the deposition of the till, from which these lumps were derived. The large limestone boulder was evidently placed in its present position at the time the shearing occurred, and its position was determined by the movements which caused the fractures.

## CAUSE OF THE FRACTURES.

The nature and the cause of these fractures in the Peoria region has long been a subject of inquiry and discussion locally. The disturbances have rendered unprofitable several ventures in mining, which otherwise could have proved successful. Before much of the field had been examined by the present author the working hypotheses that suggested themselves for the correct interpretation of these unique phenomena were either one of two; contemporaneous erosion during sedimentation, or else the collapse of extensive caverns in the underlying Silurian or Lower Carboniferous limestones. The latter theory has been used to account for some irregular faulting noted in the zinc region in Missouri*, and irregularities due to contemporaneous erosion are known from other places in the Illinois coal field.

*Structural Features of the Joplin District, C. E. Siebenthal Econ. Geol., vol. 1, p. 119.




Glacial fractures in the coal measures on Lemarsh creek near the center of sec. 10, T. 7 N., R. 7 E., looking south.

But some features were soon noted which indicated that neither of these hypotheses were tenable. The brecciation and the faulting associated with the fractures is such as to show that the sediments were essentially in the present state of induration, when the fracturing occurred, and contemporaneous filling in erosional excavations were not observed anywhere in connection with these disturbances. Such a structure as that seen in the west bank of Lamarsh creek, where the shattered and broken coal has been worked into a fault plane which cuts off the seam abruptly, and the further fact that the fractures and the associated phenomena show thrust movements in almost every instance, renders it improbable that they can be the result of collapsed caverns. Another feature which is equally difficult to account for on this hypothesis is that some of the best defined fractures run on straight courses for considerable distances. This is best shown in the sketch of the fractures in the Pottstown mine but it has also been observed in the Vickery mine. Faults due to collapsing caverns would be apt to appear more irregular in their horizontal outlines. The theory that these structures should be true structural faults is believed to be altogether untenable, for the reason that the horizontal dislocations outnumber as well as outmeasure the vertical.

The present writer believes *that the Peoria fractures are disturbances in the upper part of the soft bed rock, caused by the pressure and the motion of a continental ice sheet in Pleistocene times, that they are planes marking the outlines of immense blocks of large tracts of the uppermost coal measure strata covering tens or probably hundreds of acres of land which have been dislodged from their original position, displaced, fractured, rotated horizontally and at times vertically and partly ground into the till.* He regards the region as having been a locus of incipient glacial abrasion. In place of thoroughly triturating the grist the glacial mill here merely blocked it out of the old land on which it spent its force. The evidence which seems to demand this explanation is briefly as follows:

1. Flutings on the walls of some of the most clearly cut faults show that the movements which produced them were horizontal. Two such instances are shown on the photographs taken in the German Coal Company's mine. The flexure in the west fault on Lamarsh creek must be regarded as a fluting of the same kind. No vertical displacement between the two blocks could have left such a projection across the line of motion. Of course there is a vertical displacement here. The uplift is on the west side. But this can readily be accounted for as incidental to a much more extensive horizontal movement.

2. The locations of the fracture, so far as known, are confined to a belt following the principal drainage channels, where the preglacial topography must have been more deeply dissected than farther back in the uplands. Glacial abrasion involving the more or less intact transference of entire hilltops would naturally be most effective on a line of bluffs and on uneven topography.

3. There is a coincidence in the distribution of known disturbances of the coal and surface exposures showing plications believed to be caused by glacial push. Such plications as are shown in figures 4, 5 and 6, when they occur in a region where orogenic faults and folds are unknown, will be considered to be presumptive results of glaciation. The shattering of sandstones and sandy shales previously described are certainly also as readily accounted for by the glacial theory as any other.

4. That the locality is a place of active glacial abrasion, arrested before trituration of the till was far advanced, is shown by the occurrence of what

may be called nests of erratics which are clearly not far removed from their original place. These consist of blocks and smaller boulders of a local limestone which lies about a hundred and twenty feet above coal number 5 in the section. In preglacial time this limestone must have formed capping remnants on many buttes and small mesas in this region. It is not a conspicuous ingredient in the till, but it occurs in nests, where there are blocks occasionally measuring thirty feet in length, and where dozens of smaller boulders lie together with these in isolated limited tracts, an acre or less in extent.

5. In the absence of great vertical dislocations no other hypothesis will explain the extensiveness of the lateral displacements, which are known to exceed one hundred feet. The almost horizontal overthrusts by which one part of the principal coal seam has been pushed over another part, measure in the German mine at least thirty feet. In the Pottstown mine (Fig. 20) the coal was double over an area about a hundred feet wide and about twice that long. It is reported from this mine that at one point in the broken ground the coal seam was inverted and rested on its roof slate. This repeats the condition noted in the left bank of the Kickapoo just above Pottstown. It is evident that the horizontal motion effecting a complete rotation of even a small block of the bed rock must have been very considerable. But there is no evidence that the vertical displacement anywhere exceeds twenty or thirty feet. Where the coal is absent in the mines, the entries usually encounter the sand stones and shales which lie immediately above or immediately below the coal. A downthrow of sixty-five feet would bring the overlying coal number 6 down far enough to appear and it could not fail to be in evidence. With its overlying limestone and its characteristic middle clay seam it is a horizon readily recognized.

6. At one point in the Pottstown mine the main coal was "twisted out," the operators report, while coal number 6 lay in a horizontal position near or in its usual level above. Such a condition can not readily be accounted for as resulting from either collapsed caverns or from common orogenic faulting, but it would be the natural and expected consequence of infra-glacial disturbances involving translation of large subjacent slabs of the bed rock. The only other conceivable theory that would explain the phenomenon is that of contemporaneous erosion and this hypothesis is certainly untenable, as must be evident from the general descriptions already given.

7. Pronounced vertical planes were noted in the drift close above the bed rock at a short distance from the fractures on Lamarsh creek. This drift exposure was in the left bank of the tributary which joins Lamarsh creek from the west immediately above, and at a distance of some four hundred yards west from this. Associated with this shearing were some vertical

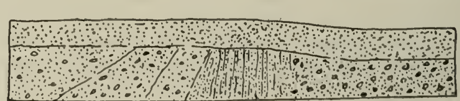


FIG. 28. Vertical fissuring and laminations in the till in the left bank of a tributary of Lamarsh creek, four hundred yards northwest of center of Sec. 10, T. 7 N., R. 7 E.

laminae of silt and sand, such as might have been formed in vertical fissures in frozen moving till, or in glacier ice. The direction of this shearing is roughly parallel to the direction of the fractures in the bed rock on the main creek. The structure is wholly unique, so far as observations on drift by the present authors extend (Fig. 28). It is regarded as indicating shearing in a vertical plane, due to differential horizontal motion in the lowest part of the till while in process of deposition.

8. In the structures on Lamarsh creek there are drift pebbles and lumps of boulder clay at least as far down as ten feet below the top of the bed rock. This is regarded as proof that the fractures are not older than the till they inclose, and as presumptive evidence that the fractures are themselves of glacial origin. Drift pebbles were also noted in one of the shearing planes in the German mine.

Clay vein in the coal and roof shales. Scene in the main entry of the German mine.

9. On the east side of Kickapoo creek in the southeast quarter of section 12, T. 8 N. R. 7 E. two wells have been drilled on the upland, which have gone through first drift, then coal measure sandstone and shale and in one case coal, in the upper one hundred feet, and below this they have been sunk for more than fifty feet through sand and gravel, clearly belonging to the drift. One such well might be accounted for by fortuitous location on an overhanging buried cliff of coal measure beds, but not very well two. Evidently a piece of coal measure strata, some hundred yards wide and thirty or forty feet thick, has been caught by the ice sheet and slid from the nearby hills and is now lodged in the drift. This appears to be an actual case of the particular kind of glacial work our explanation of the disturbances in the Peoria coal implies.

## PRACTICAL RESULTS.

These can be stated very briefly. If the fractures affecting the coal at Peoria are of glacial origin, as we believe the evidence fully proves, there is no doubt that they will be limited to places near preglacial drainage channels where the capping—excluding the drift—is scant, say less than a hundred feet, and where the preglacial topography had a comparatively high relief. In the uplands where the drift is thin, where the old land surface is more even, and where the coal has a bed rock cover of a hundred feet or more, there is little if any danger of such damage to the seam.

Some guidance in avoiding bad tracts in the fractured belt can also be obtained by examining closely all outcrops of the bed rock for such small folding, fracturing, faulting, jointing and crushing, as have here been described and figured. The presence of concretionary filling in joint planes, especially when frequent and profuse, must also be regarded as an indication of disturbance, though known to occur in some places where the coal is intact. It will be understood that the destruction of the coal is only one incident in the general fracturing of the bed rock and that the "faults" in the coal may be far to the side from the disturbances appearing on the surface.

Unlike true structural faults, which tend to run parallel, these fractures may be expected to have almost any course. The greater number have been found to vary from a northwest-southeast to northeast-southwest trend, which is in harmony with the fact that the general glacial motion was from north to south in this region.

On land where glacial disturbances affect the bed rock, explorations by the drill cannot always be trusted, unless a number of borings are made. There are cases on record where such explorations have proved misleading.

## CLAY VEINS.

The structures known among the miners as horsebacks are fissures in the coal, usually from an inch to a foot in thickness and filled with a light gray indurated clay. They are also known as clay veins. They do not offer any serious trouble to mining in this field and are probably no more frequent in this locality than elsewhere. They usually cut the coal vertically. Sometimes they are accompanied by slight faulting and this faulting may affect the fire clay as well as the roof. A typical horseback of this kind is shown in a photograph taken in the main entry of the German Coal Company's mine (Plate 20).

# Report on Field Work Done in 1907.*

(BY DAVID WHITE.)

*General*—The field operations in 1907 consisted chiefly of a study of the lower beds of the coal measures, their contact with the underlying older formations, and the search for fossils, especially plant remains, for the purpose of correlation. This work was in continuation of that begun the previous summer. The studies, which were carried on without topographic maps and in advance of detailed areal work, were in the nature of a reconnoissance; therefore, the observations both stratigraphical and paleobotanical were confined to more or less remote selected points, it being impossible to devote the time necessary for detailed tracing of the beds through the intervening areas.

Beginning with the northwestern portion of the basin, examinations were made in the vicinity of Rock Island, near Monmouth, at Colchester, Mount Sterling, vicinity of Chapin, Whitehall, Golden Eagle, and Collinsville, in passing southward. The total time spent within the limits of the State embraced about two months, the closing portion of which was given to a preliminary examination of the sections of the basal portion of the Pennsylvanian near Murphysboro, Alto Pass, Goreville, and Ozark, in the southern part of the State.

*Region North of St. Louis*—In 1906, it was found that the basal sands and clays, including the stoneware and sewer pipe clays, together with the so-called "No. 1 coal" in Rock Island county, are referable to the Upper Pottsville formation, coal No. 2 being found to date within Allegheny time. The observations made in 1907 show that the valuable stoneware clays, along the western margin of the field at all the points visited, going as far south as St. Louis, are at the same horizon and in a closely similar stratigraphic position. The local sections at Rock Island, Fairport, (Iowa), Monmouth, Colchester, Ripley, Exeter, Alsey, Whitehall, Golden Eagle, East Alton, St. Louis and Cantine near Collinsville, though variable within certain limits as to the thickness and sequence of sandstone, clays and carbonaceous beds, are in the main very much alike. Usually there is little sandstone, seldom over 20 feet in thickness, often with underlying carbonaceous matter, occupying the depressions of the old land surface. Following or intercalated with the sands, which are usually relatively free from mica, there is found more or less shaly material, the latter including inter-

*Mr. David White was couteously detailed by the Director of the U. S. Geological Survey to assist in the study of the coal fields of the State, and it is by his permission that this preliminary report is published.—H. F. B.

bedded lenses, wedges, and somewhat irregular deposits of clays, that are sometimes of great economic value over considerable areas. For lack of natural exposures and systematic prospecting the actual area and volume of these clays in their better phases suitable for stoneware or sewer pipe manufacture is largely a matter of conjecture. Without doubt, however, proper search will enormously extend the available areas of these valuable deposits. Rarely the argillaceous deposits rest directly upon the old land surface debris, the sandstone being absent. At other points there is interbedding of sandstone and clays though occasionally there is but little development of either. At no point within this area is there any great thickness of Pottsville sediments, the thickest sections observed being at Wyoming Hill, near Fairport, Iowa, and at Golden Eagle above the mouth of the Illinois river.

The fossils in the basal sandstone, resting upon the eroded Devonian in this region, appear not to be older than Sharon, at earliest. The plants from the level of the overlying stoneways clays constitute a flora apparently identical with that known from the shales at the top of the Sharon group, or in the Lower Connoquenesing in western Pennsylvania and the northern portion of the Ohio coal field. This unique and easily recognized flora, as found in Illinois, includes *Archaeopteris stricta, Cheilanthites Cheathami* var., *Alethopteris lonchitica* var., *Mariopteris inflata, Sphenopteria* sp., *Aloiopteris gracillima, Lesleya grandis, Mariopteria inflata, Danaeites* sp., *Megalopteris Southwelli, Neuropteris neuropteroides, Asterophyllites erectifolius, Lacoeia* sp., *Whittleseya elegans,* and an unpublished Ohio species of *Cardiocarpon.* Representatives of this flora are found not only in Rock Island county and vicinity, but also in association with the same stoneware clays near Colchester, Ripley, Exeter and Golden Eagle, proving the contemporaneity of these clays from St. Louis northward.

In the vicinity of Alsey, Exeter, Mount Sterling (Ripley), Colchester and Monmouth, the clays are overlain almost directly by a zone of calcareous sediments in the form of limestone lenses, boulders, or a continuous limestone sheet which may exceed 15 feet in thickness locally, although represented only by small lenses at other points. This is the limestone underlying the Colchester coal, which, in western Illinois, has usually been correlated with the Wilmington (Morris), or "No. 2 coal" of the northeastern portion of the basin, and known also as the "Third Vein" in the vicinity of LaSalle and Streator. The so-called "Coal No. 1," worked in Rock Island county, at Carbon Hill, at Cable, Sherrard, and probably also at Gilchrist's Switch, belongs, as already stated, to the Upper Pottsville. So also, I believe, does the coal worked at Gerlaw, north of Monmouth, though I was not able to enter the small county mines at this locality on account of their idleness at that time. The low coal in the small mines just to the east of Monmouth is, however, equivalent to the Colchester bed. To the same horizon belong the coal banks of Mount Sterling, Exeter, Alsey, Golden Eagle, and East Alton, and probably at Whitehall. The limestone horizon mentioned above as lying beneath the Colchester coal and just above the stoneware clays in this part of the State appears to be represented towards the south in the vicinity of East Alton, Golden Eagle, and Col-

linsville, by mere boulders which, at the two localities last mentioned, weather out in a pisolitic structure. Observations towards the extreme north of the field are not yet sufficient for a definite conclusion, but it appears probable that this calcareous horizon may be represented by the calcitic bed and Lingula fauna at Carbon City, east of Rock Island. The calcareous matter here exhibits beautiful cone-in-cone structure in fibrous calcite crystals. No trace of the limestone was observed in the Whitehall clay pits, perhaps on acount of Pleistocene erosion, but it will probably be found in the vicinity. The clays immediately above the limestone are the so-called "plastic" clays.

*Southern Margin of the Field*—The data outlined above concur in showing a contemporaneous and fairly uniform encroachment by the Upper Carboniferous sea upon the old, somewhat uneven, land surface as now revealed along the western margin of the field from St. Louis northward. It appears that this subsidence of the ancient shore occurred during late Sharon or Connoquenessing time, the thin series of deposits, including the stoneware clays, being of very late Pottsville age. Theoretically the sea should have advanced upon this old land surface from the south or southeast. It is, therefore, important as well as interesting to make some observations bearing upon this question.

Without entering in detail on the description of the southern sections hurriedly examined, it will suffice for the present, in view of the fact that the work in this part of the field is merely a beginning on the problem of the geological history of the eastern interior basin, to state briefly as possible the principal facts observed. It is found that at Sparta, the first point visited in the southern area, we have nearly 200 feet of Pottsville sediments underlying the Murphysboro coal which appears to correspond to the Colchester bed. South of Murphysboro the section at the base of the coal measures is still thicker, with the introduction of additional sandstones, shales, and thin coals, so that the section north of Alto Pass has a thickness of 300 feet or more. The lowest of these beds are apparently of Middle Pottsville age. North of Buncombe, the next point visited, my hasty and incomplete examination shows as much as 650 feet of Pottsville, the lower portion of which probably is as old as the top of the Lookout formation which constitutes the thick lower member of the Pottsville in the Appalachian trough. At Ozark, the next and last point visited, we have as great a thickness, including a number of coals, two of which appear to be locally workable at county banks.

The examination of the southern section was merely preliminary and without time for complete study from either the paleobotanical or stratigraphical stand points. In neither of the two sections last visited were plants found or collected from a sufficient number of horizons to warrant the delimitation of the upper boundary of the Pottsville. The data are, however, sufficiently complete to show that in the thick sections along the southeastern border of the field we have sediments laid down in the waters of the earlier Pennsylvania sea. From this restricted and probably narrow arm of the southern gulf, with its content of older Pottsville sediments, the waters spread by subsidence of the land until, very late in Pottsville time they eventually covered where now is the margin of the coal field north of St. Louis. In direct con-

firmation of this fact it may be noted that in the farthest of the southern sections—that at Ozark—the flora which in the northern region occurs at the base of the coal measures and which marks the time of the encroachment of the sea in that area is found in some sandy clays about 550 feet above the base of the Upper Carboniferous section. The earlier age of the lower beds in this region and the probable contemporaneity of the lowest Pennsylvanian in the State with the upper part of the lower Pottsville in the Appalachian trough, is also indicated by the fossil plants on the Illinois side of the Ohio, near Battery Rock.

*Scope of the Work*—Aside from the problems of the subdivision and correlations of the thicker sections of Southern Illinois, and in addition to the paleobotanical and stratigraphical delineation of the Pottsville-Allegheny and other boundaries, there remain certain broad and important questions concerning the physical changes and development of the eastern interior basin as a whole. One of these is to account for the considerable interval of time, as indicated by the succession in the Appalachian trough, which in western Illinois is represented by the surprisingly small interval, sometimes only a few feet, including the limestone horizon, between the stoneware clays with the Megalopteris flora and the roof of the Colchester-Murphysboro coal. Another question is that of the extent and position of the earliest Pottsville sea in southern Illinois and western Kentucky, and the history of the invasion along the Indiana side of the basin. Concerning this problem, involving the age of the various terrances, the dates of the submergence at various points, and the age reference of the coals along the eastern margin of the basin in Indiana, we have at present almost no paleobotanical data. There is, however, room for the suspicion that one or more of the important Indiana coals are Pottsville. The question of the thickness of the basal sediments and the data of the contact of the Upper Carboniferous in the northeastern portion of the basin is also related to the problem of the former connection of the Michigan basin with the eastern interior basin, on the one hand, or with the Appalachian basin, to the southeast, on the other.

During the past season very little progress was made in securing paleobotanical data from the main coal-bearing portion of the Illinois series. The small amount of material gathered harmonizes with that secured the previous season in pointing toward a Freeport age for coal No. 6 in southern Illinois. The correlation is not fully conclusive.

The flora represented by the long list of plants found in the shales a long Mazon creek in Groundy county, Illinois, present some minor obstacles to satisfactory interbasinal correlation on account of the occurrence of a number of species which are usually regarded as indicating an horizon considerably higher than that indicated by the stratigraphy, or inferred from the presence of *Neuropteris vermicularis, Ulodendron,* and other older types. Bearing in mind, however, that the species of *Odontopteris* from Mazon creek are probably less numerous than has been represented and that they belong to the Mixoneura sec-

tion of the genus, the chronological inferences drawn from the plants become less varied. It is possible that the minor differences may be found in part to be due to slight stratigraphical differences between the two principal Mazon localities. The matter of the relation of these two points and of the distribution of the plant species among them is one deserving further consideration.

# PETROLEUM FIELDS OF ILLINOIS IN 1907.

(By H. Foster Bain.)

## Contents.



*A preliminary report on the Petroleum Industry of Illinois, prepared by W. S. Blatchley, was published in 1906 and forms Bulletin 2 of the present series. In the present paper supplementary data will be found.

## INTRODUCTION.

*Production in the United States*—One of the most striking features of the recent mineral production of the United States has been the great increase in the output of petroleum. This has practically doubled in the last five years, and now reaches the enormous total of 166,000,000 barrels, having a value of over $100,000,000 in the crude state. The general features of recent production are shown in the table below, in which the figures for 1902 and 1906 are taken from the reports of the U. S. Geological Survey, and those for 1907 are the estimates of the Engineering and Mining Journal except for slight modifications introduced on the basis of later figures from Illinois.

*Production of Petroleum in the United States.*

(In barrels of 42 gallons.)

| | 1902 | 1906 | 1907 |
|---|---|---|---|
| Mid Continental | 368,849 | 21,718,648 | 47,556,906 |
| California | 13,984,268 | 33,098,598 | 40,000,000 |
| Appalachian | 32,018,787 | 27,741,472 | 25,500,000 |
| Illinois | 200 | 4,397,050 | 24,540,024 |
| Gulf-Coastal plain | 18,632,275 | 21,645,425 | 18,175,000 |
| Lima (Ohio-Indiana) | 23,358,826 | 17,554,661 | 8,030,000 |
| Others | 403,911 | 338,082 | 2,238,080 |
| Total | 88,767,116 | 126,493,936 | 166,040,000 |

These figures are not exactly comparable, but they serve to indicate with fair accuracy the principal changes in production in recent years.

As is well known, the Appalachian field was for many years the sole producer, and later long maintained a dominant position in the industry. Its output has now been practically stationary since 1880 and is at present declining. Not even extra inducements in price and grading have stimulated development enough to bring in new production as fast as old wells cease to flow, and of the 7,053 new wells drilled 27 per cent were dry, while the new daily production per well amounted to only 6.1 barrels. In southeastern Ohio 39.5 per cent of the wells drilled were dry. These figures indicate clearly that the high grade oil fields of the east are unable to respond to the demand for increased production, and that other parts of the country must be relied

on to make good the deficiency. Fortunately there seems to be no lack of good oil territory elsewhere. Aside from the Lima field, where the recent decline has been sharp and significant, the various fields either show an increase in output or are clearly capable of yielding more oil if development be pushed.

The most important increases in oil production in recent years have been in the Mid-Continental (Kansas-Oklahoma) and the Illinois fields. As shown by the tables already quoted, the former is now the leading American oil field. The Illinois production, while not so large, is from a younger field and is sufficient to more than compensate for the decline in the output of the Lima district.

*Production in Illinois*—While attempts to find oil and gas in Illinois date back in 1853, and in Montgomery county a small field was developed in 1886 which continued in production up to 1902, the present petroleum industry of southeastern Illinois dates from 1904 only. As early as 1865, six wells were drilled in the heart of what is now the productive territory of Clark county, but the showing being small the work was abandoned. Enough oil was, however, found to lead to renewed drilling in 1904, when J. J. Hoblitzel & Son rediscovered this field. Shipments began in June, 1905, and since that date the increase in production has been rapid. The total shipments from the field have been as follows:

*Production of Crude Petroleum in Illinois.*

(In barrels of 42 galloms.)

| | 1905* | 1906 | 1907 |
|---|---|---|---|
| January | .............. | 55,680* | 752,670† |
| February | .............. | 65,209* | 918,620† |
| March | .............. | 19,352* | 1,494,598† |
| April | .............. | 102,862† | 1,823,024† |
| May | .............. | 267,746† | 2,094,194† |
| June | 5,489 | 410,654† | 1,830,633† |
| July | 9,208 | 610,401† | 2,376,281† |
| August | 15,092 | 778,463† | 2,398,895† |
| September | 19,592 | 722,168† | 2,560,592† |
| October | 26,444 | 463,819† | 2,818,952† |
| November | 34,766 | 350,985† | 2,464,980† |
| December | 45,912 | 538,130† | 2,201,265† |
| Tank car shipments 1907 | .............. | .............. | 806,234* |
| Totals | 156,503 | 4,385,939 | 24,540,938 |

*Tank car shipments.
†Pipe line run, Ohio Oil Co.

Up to and including March, 1906, all shipments were made in tank cars only. In April the first pipe line reached the district, and since then the lines of the Ohio Oil Co. have been rapidly extended until

they now reach all the pools and carry oil both to the eastern refineries and to the new Wood river plant, opened in 1907, near Alton. In addition, the Robinson Oil Refining Co. has built at Robinson, and the Sun, Cornplanter and a number of other companies ship by tank cars.

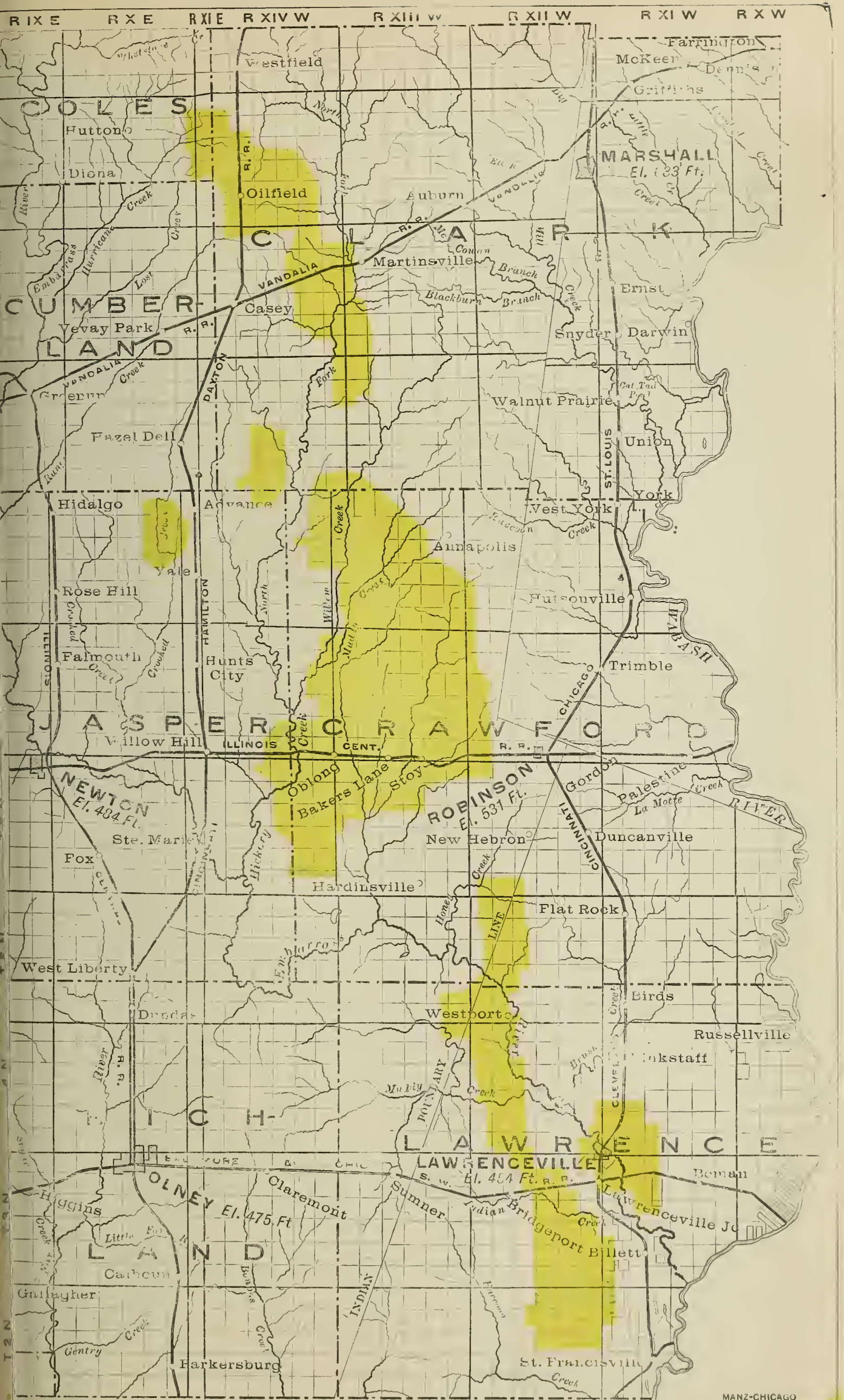
The figures given above do not show the entire production, since there is always a large amount held in storage by the producers. The pipe lines have not been able to handle all the oil offered, despite the rapid rate at which they have been extended. Accordingly the true producing capacity of the field has not yet been tested. As illustrating some of the difficulties involved in handling such enormous quantities of oil, it may be stated that on January 1st, 1908, the Ohio Oil Co. had stored 12,610,618 barrels, and is constantly building additional tanks. The pipe line runs for the first six months of 1908 amounted to 17,694,759 barrels, and the total storage July 1st was 20,352,880 barrels.

In 1907 the development of the field was particularly active. The area was extended rapidly to the southeast, many gaps were filled in, new and lower sands were tapped, additional pipe lines were laid, a new refinery was built and the output was phenomenal.

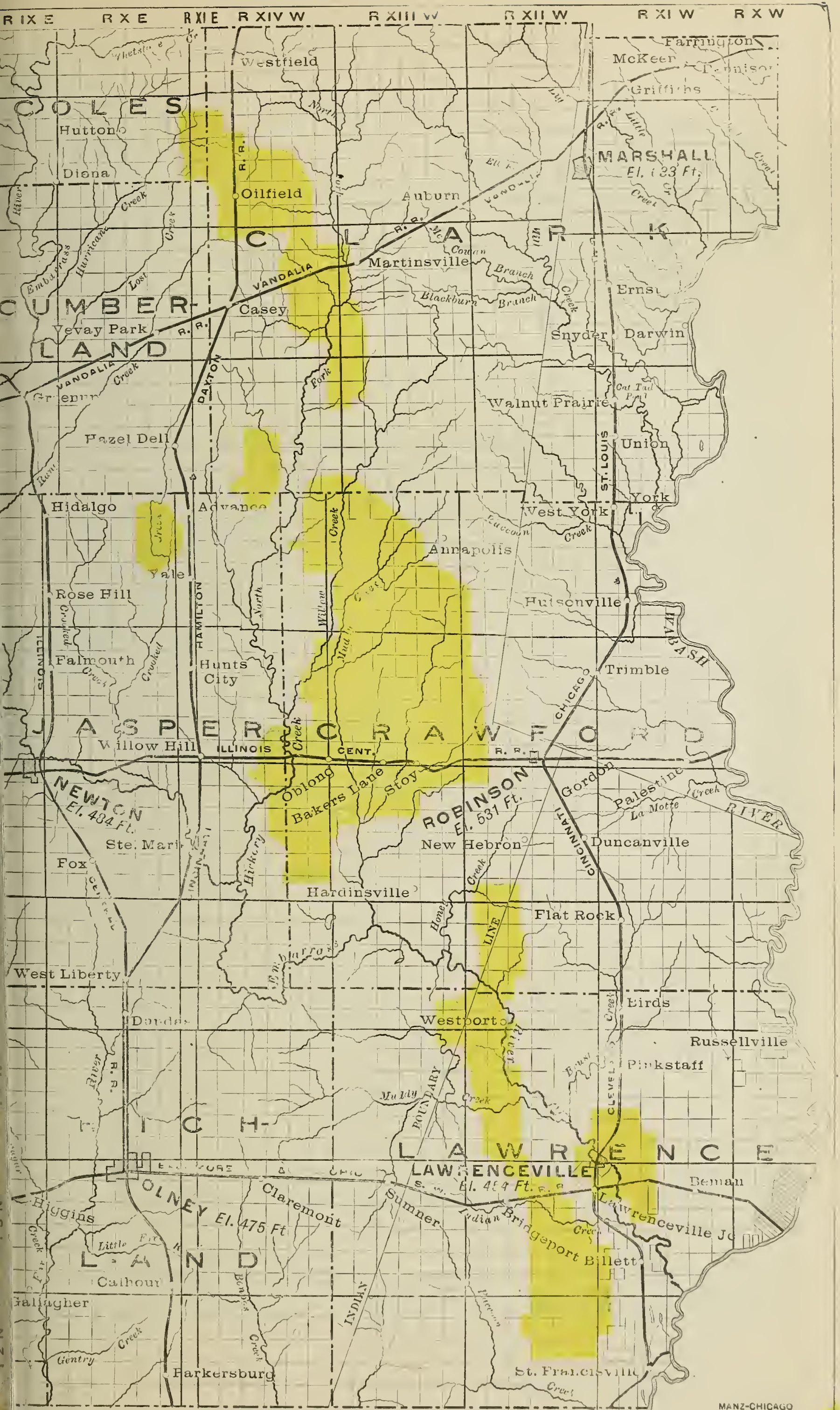
At the close of the preceding year the number of producing wells was estimated at 4,185, and 532 dry holes were known to have been drilled. The total number of producing wells January 1, 1908, may be estimated at 9,772, with 1,260 dry holes. At this rate 88 per cent of the holes put down have proved productive, despite the fact that the outlines of the field are at many points yet to be determined. The new production for the year may be estimated at 139,163 barrels daily. The detailed figures for the year are given in the accompanying table, being derived from the careful monthly records of the Oil City Derrick:

*Wells Drilled in Illinois, 1907.*

| Month. | Complete. | Production barrels. | Aver. Initial Production barrels. | Dry Holes. |
|---|---|---|---|---|
| January | 253 | 9,433 | 44 | 41 |
| February | 356 | 9,842 | $32\frac{2}{3}$ | 55 |
| March | 351 | 10,392 | $35\frac{5}{7}$ | 60 |
| April | 387 | 11,083 | 32 | 40 |
| May | 493 | 13,329 | 31 | 64 |
| June | 639 | 18,807 | $33\frac{1}{3}$ | 75 |
| July | 521 | 17,375 | $38\frac{3}{4}$ | 72 |
| August | 461 | 11,240 | $27\frac{1}{8}$ | 45 |
| September | 400 | 10,967 | $32\frac{1}{3}$ | 62 |
| October | 363 | 8,157 | $25\frac{1}{2}$ | 82 |
| November | 430 | 9,780 | $28\frac{1}{4}$ | 80 |
| December | 334 | 8,758 | $31\frac{1}{7}$ | 52 |




Map showing producing oil pools in Southeastern Illinois.




Map showing producing oil pools in Southeastern Illinois.

*Summary by Counties.*

| County. | Complete. | New Production. | Dry Holes. |
|---|---|---|---|
| Crawford | 2,840 | 83,263 | 376 |
| Clark | 1,176 | 30,385 | 201 |
| Lawrence | 690 | 30,543 | 70 |
| Cumberland | 152 | 3,612 | 13 |
| Coles | 56 | 314 | 11 |
| Edgar | 25 | 118 | 14 |

This enormous development was accomplished in a thoroughly business like and quiet manner. Leases are selling at very good prices, and a bonus of $150 to $200 an acre with a royalty of one-eighth is not uncommonly demanded in the productive district. At the same time there was little speculation by those not familiar with the oil business and its risks. Practically none of the usual stock peddling companies were organized, and there is a strong sentiment against them.

Experienced men have found this field an unusually profitable one despite the high bonus asked and certain other drawbacks. One conservative operator estimates that three out of four will make money. It is by no means unusual for a well to flow enough oil to pay for itself by the time it is connected up, and initial productions of 1,000 barrels occur. So far the wells have stood up well under pumping. The most northerly, or Westfield pool, is the only one which is even approximately drilled in. It was here that the oil was first found and the shallow depth, 350 to 400 feet, has made its exploitation rapid. In October a careful estimate showed that the wells of this pool were yielding an average of about six barrels daily, and many of them had been pumped more than two years. The Crawford county wells were at the same time estimated to be yielding twenty barrels, while those of Lawrence county were yielding forty barrels.

The approximate limits of the producing territory, so far as developed, are shown on the accompanying map (plate 21). It will be noted that the territory extends from Clark and Cumberland counties southeast through Crawford and into Lawrence. Beyond the latter, in Gibson county, Indiana, there is an additional pool at Princeton. The productive strip has a proven length of approximately eighty miles. In breadth it varies from a general width of two or three miles to an exceptional one of ten or twelve. The limits are as yet but poorly defined by drilling and additional territory is constantly being brought in, though for much of the distance shown on the map there is a fairly consistent line of dry holes, both to the east and west of the territory indicated as productive.

Outside this district there is no regular oil production in Illinois, though oil has been found at a number of points as detailed elsewhere.

## COMPOSITION AND PROPERTIES OF PETROLEUM.

*Chemical Composition*—Petroleum is not a definite chemical compound, and the name is used to cover a wide variety of mineral oils occurring in the rocks. F. W. Clarke has recently reviewed the literature and discussed the composition and character of the group of natural hydrocarbons, to which petroleum belongs. It will be sufficient here to note that: "Natural gas, petroleum, bitumen and asphaltum are all essentially compounds of carbon and hydrogen; or, more precisely, mixtures of such compounds in bewildering variety. They contain, moreover, many impurities—sulphur compounds, oxidized and nitrogenous substances, etc.—whose exact nature is not always defined. * * * * * * * All the hydrocarbons fall primarily into a number of regular series, to each of which a generalized formula may be assigned."*

Of these series, the eight following have been discovered in petroleum:

1. $CnH_2+2$
2. $CnH_2n$
3. $CnH_2n—2$
4. $CnH_2n—4$
5. $CnH_2n—6$
6. $CnH_2n—8$
7. $CnH_2n—10$
8. $CnH_2n—12$

Clark considers these formulas as being of only preliminary value. The first represents the paraffin group and begins with march gas or methane and ranges through a series of liquid compounds to solids, such as ordinary paraffin. March gas ($CH_4$) is the most important constituent of natural gas, and the larger number of American petroleums belong to the paraffin series.

A small amount of sulphur is found in practically all petroleums. In part, it is believed to be in chemical combination, although free sulphur has been found in the Texas soils. Nitrogen is nearly always present, from a trace up to 1 per cent and over. It seems to be in chemical combination, but has not yet been thoroughly studied. Asphalt and the solid hydrcarbons are most generally considered to be the oxidized residue of normal petroleum exposed to the acid, but the matter is not wholly beyond doubt. Such materials are especially characteristic of seepages.

Ultimate analysis shows petroleum to consist essentially of carbon and hydrogen. In the table below are given analyses of a few representative crude oils:

*Chemical Composition of Petroleum.*†

| Source of oil. | Carbon. | Hydrogen. | Oxygen. |
|---|---|---|---|
| West Virginia—heavy | 83.5 | 13.3 | 3.2 |
| Pennsylvania—light | 84.3 | 14.1 | 1.6 |

*Clarke, U. S. Geol Survey, Bull. 330, p. 619.
†Boverton Redwood, Petroleum and Its Products, London, 1906, p. 210.

*Physical Character*—Crude oils vary greatly in physical as well as chemical properties. The most important variations are in specific gravity, viscosity, capillarity, color, odor and heating and illuminating power. Variations in the last named are the most important.

For comparison with the analyses given above, the following analyses of a few coals may be quoted:

*Chemical Analyses of Cei tain Coals.**

| Coal. | Hydrogen. | Carbon. | Nitrogen. | Oxygen. | Sulphur. | Ash. |
|---|---|---|---|---|---|---|
| Ill. No. 3 | 4.92 | 67.30 | 1.43 | 12.99 | 1.77 | 11.59 |
| Pa. No. 1 | 4.20 | 81.98 | 1.36 | 3.56 | 1.49 | 7.41 |
| W. Va. No. 6 | 4.70 | 83.62 | 1.70 | 4.23 | .66 | 5.09 |

While the two sets of analyses are not, perhaps, strictly comparable, the much higher content of the oil in carbon and hydrogen is at once apparent, and this is largel ythe explanation of its higher value as a fuel. In addition, the liquid form permits of burning so as to produce more complete combustion and saves the specific heat used in converting the solid fuels. Direct comparison of the calorific values is given below:

| Clorific Power of Certain Fuels.† | B. T. U. |
|---|---|
| Heavy petroleum from West Virginia | 10,180 |
| Light petroleum from Pennsylvania | 9,963 |
| Heavy petroleum from Baku | 10,800 |
| Light petroleum from Baku | 11,460 |
| Coal | 7,500 |
| Coke | 6,500 |
| Peat | 4,500 |
| Wood | 2,500 |

These figures are of only general value, but will illustrate the greater value, weight for weight, of oil, when compared with other fuels.

Illuminating power is also a most important property of petroleum. It contains certain compounds which burn with a luminous flame, and one of the important uses of even the heavier portion of the crude oil is the enrichment of gas made from other materials to make it available for illuminating purposes.

The specific gravity of a crude oil is mainly important as measuring the relative yield of light and heavy oils on distillation. It is usually measured on what is known as the Baumé scale. Below is given the gravity of various American oils:

*U. S. Geol. Surv., Prof. Pap. No. 48, pt. 1.
†Redwood, Op. Cit. p. 210.

*Specific Gravity of Various American Oils.*

| | Sp. Gr. | Baumé. |
|---|---|---|
| Pennsylvania—* | | |
| Bradford | .810 | 43 |
| Ohio—* | | |
| Macksburg | .829 | 39 |
| Lima | .839 | 37 |
| Wyoming* | .912 | 24 |
| California—* | | |
| Puente | .880 | 29 |
| Coalinga | .979 | 13 |
| Colorado—* | | |
| Boulder | .806 | 44 |
| Texas—* | | |
| Spindletop | .876 | 30 |
| Oklahoma—* | | |
| Bartlesville | .859 | 33 |
| Illinois—† | | |
| Weaver lease | .887 | 28 |
| Briscoe lease | .873 | 30 |
| Birch lease | .870 | 31 |

*Redwood, Op. Cit. p. 196.
†Grout, F. F., State Geological Survey (Illinois) Bulletin 2, p. 100.

The properties of capillarity, flashing point, viscosity, etc., are important principally in the derivatives of a crude oil, as measuring their availability for certain uses. No complete study has yet been made of Illinois oils, and the reader is referred to Boverton Redwood's treatise for a discussion of the subject in general. It may be remarked that the properties of the product derived from any oil are to some extent determined by the process of refining, and are therefore to a slight extent under control. For this reason fractional distillations of the crude made in a laboratory are of only limited value in determining the relative commercial importance of different oils.

*Illinois Oils*—Illinois petroleums have only recently been studied chemically, though some preliminary work was done by F. F. Grout and published in connection with Blatchley's report on the district.*

The oil in the main grades about 32° and sells for 68 cents a barrel. A limited amount grading below 30° is purchased at 60 cents. This low grade oil is sold for fuel, but the great bulk of the output goes to the refineries, its content of the higher oils being sufficient to make it highly desirable. It is dark olive green in color and the sulphur content runs below 1 per cent. Careful studies of its chemical properties made by Dr. David T. Day of the U. S. Geological Survey are summarized in the accompanying table.

The samples were examined as to odor, color, and specific gravity, and then distilled by the Engler distilling apparatus, the quantity distilling up to 150° C. being classed as naphtha, and that between 150° and 300° C. as burning oil. The determination of the sulphur content of the oils was made in the Pittsburg laboratory of the Survey.

*State Geological Survey (Illinois) Bulletin 2, p. 100.

The methods used in these oil tests have been selected because of their simplicity, which enables them to be carried rapidly to completion, and the treatment of all the samples in precisely the same manner affords a basis for a just comparison of the oils. In the first series of tests oils from 34 samples were examined.

The oils range in gravity from 39.5° B. in the deep wells (1,500 feet) in the Bridgeport pool to 22.3° B. in the Duncansville pool. Some of the shallow wells (300 feet) in the north end of the field also yield oils as light as 35.5° B.

No oil was found with more than half of 1 per cent of sulphur, and this only in the extreme north end of the field. Farther south the average is about one-fourth of 1 per cent and the oils are acceptable as non-sulphur oils. Pipe-line samples from all pools averaged still less—that is, 0.2 per cent.

The percentage distilling below 150° Centigrade ranged from 1 to 21, averaging 13.2 per cent for the State. The burning oil averaged 31.2 per cent.

Most of the oils contained practically no asphalt and considerable proportions of paraffine wax."

## Mode of Occurrence of Gas and Petroleum.

Petroleum is very generally distributed throughout the sedimentary rocks. Numerous tests have shown that it is present in small quantities in shales, limestones and sandstones of widely varying age and character. Dr. Edward Orton has estimated that in the Ohio black shale, when the latter is 1,000 feet thick, the amount present would amount to more than ten million barrels to the square mile.* Dr. T. Sterry Hunt† has estimated that the Niagara limestone at Chicago contains 7,743,745 barrels of petroleum per square mile, assuming that the petroliferous portion is only thirty-five feet thick.

The problem, therefore, is not so much the presence of the oil as its accumulation in quantity. The conditions under which it occurs in nature have been much discussed, and were summarized by Professor Blatchley in his report upon the Illinois petroleum fields.* They may now be most generally stated to include the presence of (1) a porous rock, to contain the oil or gas; (2) an impervious cover; (3) geologic structure which will permit their accumulation. To produce flowing wells, pressure of some sort is necessary, and a most common accompaniment of oil and gas is salt water.

The necessity of the porous rock is clear when it is reflected that oil pools are very seldom, if ever, actual cavities or open spaces. In nearly every instance the oil or gas merely occupies the pores or open spaces in some rock. Since of the common sedimentary rocks sandstone is the most porous, it is the one in which the oil most commonly occurs. From this has arisen the custom of referring to any rock in which petroleum is found as a "sand." Actually many of the best "oil sands" are not sand at all in a geological sense, but are limestones, dolomites or even shales. The latter are so dense as seldom to serve directly as oil containers.

*Geological Survey of Ohio, vol.VI, p. 413-414.
†Chemical and Geological Essays, p. 173.
‡State Geological Survey (Illinois), Bulletin 2, p. 25.

Next to sandstones, dolomites and magnesian limestones most frequently serve to hold the oil.

In the Illinois fields, so far developed, the productive wells are usually in true sands. The "gas sand" exploited at Pittsfield, in Pike county, is, however, the Niagara dolomite; and in the Westfield pool of the Casey district certain wells find their supply of oil in one of the coal measure limestones. This limestone, as found outside the productive area, is non-magnesian, but the following analyses show that locally it is highly magnesian, and that, in fact, the more magnesian it is the more oil it contains.

*Analyses of Samples of Drillings from Well No. 8, Briscoe Lease, Southwest Quarter Section 29, Township 11 N., Range 14 W., Parker Township, Clark County, Illinois.*

F. F. Grout, Analyst.

| | Above best pay 361-365 feet. | In best pay 380-385 feet. | Below best pay 395-400 feet. |
|---|---|---|---|
| Calcium carbonate ($CaCo_3$) | 46.38 | 51.38 | 55.16 |
| Magnesium carbonate ($MgCO_3$) | 20.69 | 28.76 | 17.64 |
| Iron oxide and alumina ($Al_2O_3Fe_2O_3$) | 10.93 | 3.71 | 2.47 |
| Insoluble | 21.69 | 11.45 | 24.47 |
| Totals | 99.69 | 95.30 | 99.74 |

Drillings from just above the pay, at a depth of 361-365 feet, showed under the glass as angular fragments of a grayish close-grained limestone, with crystals of calcite, iron pyrites and particles of shale intermingled. Drillings from the best pay, 310 to 385 feet, were much darker in hue, due to the brownish discoloration by the oil. Under the glass they resemble a miniature mass of water worn gravel, the fragments being rounded instead of angular and loosely cemented in small bunches. Less pyrites and no shale were visible. The layer below the oil pay was more like that from above, the fragments being angular there, though darker in color.

The relation of the oil's accumulation to the more magnesian portions of a limestone formations has been previously noted and was studied by Orton, who placed much weight upon this feature. The simple explanation is that the dolomitic portion of the rock being more porous acts as a reservoir. That this enters into the explanation can not be doubted, but the Westfield occurrence raises some doubt whether this be the whole of the matter. The coal measure limestone in which the oil occurs here is one of a number widely outcropping throughout the State. It is, where exposed at the surface, particularly free from magnesia; and, in fact, so far as present observation goes, none of the coal measure limestones at or near this horizon are magnesian except within the small area where the oil occurs. Samples blown from the wells here are not distinguishable lithologically from the Trenton limestone of Indiana, and show that the rock is a coarse porous dolomite very similar in general appearance to the Galena dolo-

mite of the northwestern part of the State. This striking local change in the character of the rock, coincident as it is with the accumulation of oil in his and other rocks, at least fairly raises the question whether the magnesia did not come in with the oil rather than antecedent to it, or whether both are not in some way connected with a common cause. This question must, for the present, remain unanswered.

The necessity for an impervious cover arises from the low specific gravity of gas and oil and the high capillarity of the latter. In any saturated rocks both gas and oil, in the absence of a cover, would be forced to the surface and escape. Even in dry rocks the gas and the lighter portion of the oils will escape until, as seems actually to have occurred in California, the heavy residue seals of the pores of the rock and makes a cover. In the Illinois field, as commonly elsewhere, shales form a sufficiently impervious cover and prevent the escape of the gas and oil, even when considerable pressure has been generated.

The structural conditions which favor the accumulation of gas and oil are varied. Granted the presence of sufficient porous rock and of disseminated oil, the actual point of accumulation may be either an anticline, in a syncline, on a terrace or a flat, and the most important determining factor seems to be the wetness or dryness of the rock.

Mr. W. T. Griswold has recently discussed this subject* and announces the following conclusions:

"In dry rocks the principal points of accumulation of oil will be at or near the bottom of the synclines or at the lowest point of the porous medium, or at any point where the slope of the rock is not sufficient to overcome the friction, such as structural terraces or benches. In porous rocks completely satuated the accumulation of both oil and gas will be in the anticlines or along level portions of the structure. Where the area of porous rocks is limited the accumulation will occur at the highest point of the porous stratum; and where areas of impervious rocks exist in a generally porous stratum the accumulation will take place below such impervious stop, which is really the top limit of the porous rock. In porous rocks that are only partly filled with water the oil accumulates at the upper limit of the saturated area. This limit of saturation traces a level line around the sides of each structural basin, but the height of this line may vary greatly in adjacent basins and in different sands of the same basin.

"Partial saturation is the condition most generally found, in which case accumulations of oil may occur anywhere with reference to the geologic structure. It is most likely, however, to occur upon terraces or levels, as these places are favorable to accumulation in both dry and saturated rocks.

"Under all conditions the most probable locations for the accumulations for the accumulation of gas are on the crests of anticlines. Small folds along the side of a syncline may hold a supply of gas, or the rocks may be so dense that gas may not travel to the anticline, but will remain in volume close to the oil."

Mr. Griswold's observations are of particular interest, since they are based on studies of oil in rocks of similar age and character to

* U. S. Geological Survey, Bulletin 318, p. 15.

those in which most of the oil and gas in Illinois have been found. Data are not at hand for making a complete application of his conclusions to our own field. In southeastern Illinois the oil and gas so far discovered are all under a broad shallow anticline, the presumable southeastern extension of that which crosses the Illinois river at LaSalle.* While dry sands are present in the region, the oil is found in those that are not, and several sections made across the field show that it is crowded up and under the crest of narrow arches. Along the south line of Westfield township, in Clark county, the productive horizon rises 100 feet in an arch four miles wide. Beyond that the sand is wet or non-porous. Along the south edge of Parker township of the same county an arch 129 feet high and two miles wide is found with the oil again under its crest. A similar east-west section across the center of the Siggins pool, in Cumberland county, shows an arch sixty-eight feet high and four miles wide. Beyond these limits it has not been traced. South of Casey and Martinsville, in Casey township, level lines to various points on the Quarry creek limestone show a similar arch to be present. Other portions of the field have not yet been studied in sufficient detail to make out the structural features.

Whether these arches are true anticlinals and deformational in origin can not be positively affirmed. They may represent original inequalities in the thickness of particular beds or even, in part, the effect of unequal settling during consolidation of the beds. On the whole, this seems unlikely in the case of arches of the breadth noted above. Certain instances observed elsewhere in the field of sharp differences in the depth to the sand where the surface level was the same, leads to the inference that irregularities in the original distribution of the sand beds will be found to be very important in the distribution of the productive and barren areas in minor detail. Here, as elsewhere, dry holes are encountered in the midst of productive territory, and rich and barren streaks are woven together in a somewhat irregular pattern when projected on a horizontal plane.

Outside the southeastern area also the oil and gas so far found has been under anticlines or terraces.

## Petroleum Bearing Rocks of Illinois.

### general sections.

The general geology of the State has been very briefly discussed by Stuart Weller* in connection with preliminary geological map of the State. Additional data of importance have been given by David White,† and published elsewhere in this volume by T. E. Savage and by Weller. From these and other sources the following general sections have been compiled. In preparing these sections no attempt has been made to reconcile differences of nomenclature or classification, the terms adopted being merely those in general use, though not always exactly as here.

*Weller: State Geological Survey, (Illinois) Bulletin 6, p. 11.
* State Geological Survey, (Ill.) Bulletin 1; also (new edition) Bulletin 6.
† State Geological Survey (Ill.) Bulletin 4, pp. 201-203.

NORTHERN ILLINOIS SECTIONS.

This section is intended to be representative for that portion of the State lying north of Rock Island, LaSalle and Kankakee.

| | |
|---|---|
| Carboniferous. (Pennsylvanian.) | Coal measures, mainly lower; consisting of coal, shale, sandstone and limestone; 575 feet thick; no known gas or oil.<br>Unconformity. |
| Devonian. | Limestone; 150 feet thick.<br>Unconformity. |
| Silurian. | Niagara limestone; dolomite; 335-388 feet thick; containing *frequent seepages of bitumen in the vicinity of Chicago.*<br>Unconformity. |
| Ordovician. | Cincinnatian shales and limestone; 68-250 feet thick.<br>Unconformity.<br>Galena-Trenton; mainly dolomite, a little limestone and shale at the base; 300-440 feet; a very persistent *oil "rock" or petroliferous shale in the lower portion.* St. Peter sandstone; friable sandstone 150-275 feet; heavily water bearing.<br>Lower Magnesian dolomitic limestone; 450-811 feet, all but upper part known from well records; rests on Potsdam sandstone known only from well records. |

*Central Illinois Section.*

For the region south of Rock Island, LaSalle and Kankakee, and north of the mouth of the Illinois river and Danville.

| | | |
|---|---|---|
| Carboniferous. | Pennsylvanian. | Coal measures, upper; coal, shale, limestone, and sandstone; 600-700 feet thick.<br>Coal measures, lower; coal, shale, sandstone and coal including approximately from "No. 2 coal" to "No. 6 coal;" 300 feet thick.<br>Pottsville equivalents, including coal, clay, shale, and sandstone; mainly the beds associated with the "No. 1 coals" of the western part o fthe State and irregular thickness, found in deep borings elsewhere; 50-150 feet thick; *small amounts of oil and gas reported, but origin not certain.*<br>Unconformity. |
| | Mississippian. | Chester; irregular thickness of sandstone, shale and limestone, recognized in a few borings; generally absent in this territory; 0-50 feet thick.<br>Unconformity.<br>St. Louis, Salem, Ste. Genevieve; limestone, non-magnesian, partly cherty and partly oolitic; 50-100 feet thick. Osage group, Warsaw, Keokuk, and Burlington; shales and limestone, the latter often cherty; 250-350 feet thick; crude petroleum in geodes near the top of the Keokuk.<br>Kinderhook; shales, limestones and sandstones; 80-150 feet thick.<br>Unconformity. |
| Devonian. | | Limestone, 15 feet.<br>Unconformity. |
| Silurian. | | Niagara; dolomite; 50-120 feet thick; *gas at Pittsfield in Pike county, and oil seepage in Calhoun county.* |
| Ordovician. | | Cincinnatian; shales; 40-100 feet thick.<br>Unconformity.<br>Galena-Trenton; dolomite; 300-400 feet thick; *oil seepage in Calhoun county.*<br>St. Peters; sandstone; 130 feet exposed; heavily water bearing. |

*Southern Illinois Section.*

For the area south of the mouth of the Illinois river and Danville, including the principal oil and gas producing districts.

| | | |
|---|---|---|
| Tertiary. | | Lafayette, Porters Creek and Lagrange; sands; clays and ferruginous conglomerate; found in extreme southern counties only; 150 feet thick. |
| Cretaceous | | Ripley; sands and clays in extreme southern portion of the State only; 20-40 fet thick.<br>Unconformity. |
| Carboniferous. | Pennsylvanian. | Coal measures, upper; coal, shale, sandstone and limestone; 500-700 feet thick; *contains the oil and gas sands of the Westfield. Siggins and Casey pools.*<br>Coal measures, lower; coal, shale, sandstone and limestone: 400-650 feet thick; *including probably the lower pay of the Johnson township pool in Clark county, and possibly the Robinson sand.*<br>Pottsville equivalents, including Mansfield sandstone of Indiana; sandstone, conglomerate, shale, and thin coals; 50 to 500 feet thick; including the *Buchanon sand and probably the Robinson and Bridgeport sands, with the greater part at least of the productive sand of Montgomery county.*<br>Unconformity. |
| | Mississippian. | Chester group; limestone, shales and sandstones, usually three well defined limestones (non-cherty) and frequently with red shale at the base; 500 feet thick; *includes the Kirkwood oil sand of Lawrence county, the oil sand at Princeton, Indiana. had a showing of gas at Vincennes, and the gas and oil sands at Sparta in Randolph county.*<br>Cypress; sandstone, massive, coarse grained and fairly regular in thickness which amounts to 80 to 150 feet; not known to have been prospected for gas or oil.<br>Unconformity.<br>Ste. Genevieve, St. Louis and Salem; limestone, partly cherty and partly oolitic; 250-400 feet thick.<br>Osage group (Burlington, Keokuk, Warsaw); limestones often cherty with some shale; 200 feet thick.<br>Kinderhook; mainly shale, some limestone; 50 feet thick. |
| Devonian. | | Limestone, sandstone, shale; limited in outcrop to southern counties; 500-700 ffet. |
| Silurian. | | Niagara and Clinton; limestone; in southern counties only; 100-110 feet thick. |
| Ordovician | | Cincinnatian; limestone, shale and sandstone; 100 feet thick.<br>Unconformity.<br>Galena-Trenton; limestone, non-magnesian; 80 feet thick. |

## GAS IN THE PLEISTOCENE DEPOSITS.

In the above general sections no account has been taken of the thickness of glacial deposits and other surface material which everywhere mantle the harder rocks. Natural gas is found in these deposits in small quantity at a number of points throughout the State. Such wells are or have been known near Champaign, Princeton, Colchester, Wapella, Heyworth, and elsewhere. The pressure is usually slight

and the life of the individual wells is usually short. While it is not possible in every case to absolutely exclude the possibility of these wells representing leakage from lower reservoirs, a sufficient explanation of them is believed to be found in the decay of woody material buried in the drift itself. These wells are characteristically difficult to maintain owing to sand clogging the pipes.

## CARBONIFEROUS OIL HORIZONS.

*General Character of the Rocks*—As is indicated in the above general sections, the principal horizons so far found to be productive of oil and gas in this State are in the Carboniferous rocks. The sands are found in both the upper and lower coal measures, the rocks of Pottsville age, and in the Chester group of the Lower Carboniferous or Mississippian. Owing to the absence of a good marker it is not as yet always possible to say whether a given sand is in the lower coal measures or in the upper part of the Pottsville rocks. There are also so many variations in the lithology of the coal measures that it is difficult to correlate individual horizons with certainty. There is marked unconformity at the top of the Chester, and many facts suggest another unconformity at the base of the coal measures.

The following well records will serve to illustrate the character of the rocks of this region. The first record is that of a well in the heart of the Casey pool (Sec. 28, T. 11N., R.14W.), the samples having been collected by T. E. Savage while the well was being drilled. The second and third are from carefully recorded diamond drill work. The holes are in southeastern Illinois, not far from the oil territory. The fourth is the Delafield diamond drill record studied by Mr. Jon Udden and published in the Year-Book for 1906. The fifth is the record of one of the early holes at Robinson, published by Blatchley.* The sixth is a record from Lawrence county (Sec. 36, T.4N., R.VXIII E.) supplied by the courtesy of the Everson Oil Co. The last is a record from Wabash county (Sec. 36, T.1N., R.13E.)

*State Geological Survey (Illinois), Bulletin 2, p. 62.

*No. 1. Gillespie Well Record.*

| | | Thickness. Feet. | Depth. Feet. |
|---|---|---|---|
| 1 | Drift | 18 | 0—18 |
| 2 | Gray shale | 25 | 18—43 |
| 3 | Shale with coal fragments | 5 | 43—48 |
| 4 | Reddish shale | 6 | 48—54 |
| 5 | Gray shale | 5 | 54—59 |
| 6 | ..do | 6 | 59—65 |
| 7 | Arenaceous gray shale | 5 | 65—70 |
| 8 | Gray sandy shale | 16 | 70—86 |
| 9 | Fine sand | 6 | 86—92 |
| 10 | No sample | 6 | 92—106 |
| 11 | Fine grained gray sandstone | 5 | 106—111 |
| 12 | Fine grained micaceous sandstone | 12 | 111—123 |
| 13 | Gray micaceous sandstone; some oil | 11 | 123—134 |
| 14 | Sandstone with seam of coal | 6 | 134—140 |
| 15 | Gray shale with coal fragments (perhaps from No. 14) | 5 | 140—145 |
| 16 | Limestone | 17 | 145—162 |
| 17 | Shale with small amount of sand | 5 | 162—167 |
| 18 | Drab shale | 5 | 167—172 |
| 19 | Gray sandy shale | 3 | 172—175 |
| 20 | Gray shale | 6 | 176—181 |
| 21 | ..do | 10 | 181—191 |
| 22 | ..do | 11 | 191—202 |
| 23 | ..do | 10 | 202—212 |
| 24 | ..do | 5 | 212—217 |
| 25 | ..do | 11 | 217—228 |
| 26 | Shale with seams of coal | 5 | 222—233 |
| 27 | Gray shale | 5 | 233—238 |
| 28 | ..do | 6 | 238—244 |
| 29 | Gray shale with coal | 11 | 244—255 |
| 30 | Gray shale | 4 | 255—259 |
| 31 | Drab shale | 5 | 259—264 |
| 32 | Fine grained sandstone with pyrite | 6 | 264—269 |
| 33 | Argillaceous sandstone | 5 | 269—275 |
| 34 | Gray shale | 9 | 272—282 |
| 35 | Black shale | 5 | 282—287 |
| 36 | Argillaceous sandstone | 4 | 287—291 |
| 37 | Sandstone with pyrites. (Driller called this top of oil rock) | 10 | 291—301 |
| 38 | Calcareous sandstone. (Driller said this corresponded to the limestone oil rock found one-half to one mile northwest) | 5 | 310—306 |
| 39 | Impure sandstone | 5 | 306—311 |
| 40 | Gray argillaceous sandstone | 5 | 311—316 |
| 41 | Brown shale | 10 | 316—326 |
| 42 | Black shale | 5 | 326—331 |
| 43 | White sand. (Driller called this lower oil sand) | 10 | 331—341 |
| 44 | Gray sandstone | 5 | 341—346 |
| 45 | Sandstone, rather course: some oil. (Oil sand of drillers when oil is not in limestone) | 5 | 346—351 |
| 46 | Sandstone similiar to No. 45. (Drillers say oil should have been found in 45 and 45) | 5 | 351—356 |
| 47 | Gray sandstone | 15 | 356—371 |
| 48 | Sandstone, with mica flakes | 5 | 356—376 |
| 49 | Sandstone with much water | 5 | 376—381 |
| 50 | Dark sandstone | 5 | 381—386 |
| 51 | Gray sandy shale with small amount of lime | 5 | 386—391 |
| 52 | Dark gray shale limestone | 5 | 391—396 |
| 53 | Dark shaly limestone | 5 | 396—401 |
| 54 | Dark shale | 5 | 401—406 |

*No. 2 Diamond Drill Hole.*

| | | Thickness Feet. | Thickness Inches. | Depth Feet. | Depth Inches. |
|---|---|---|---|---|---|
| 1 | Yellow clay | 12 | | ........... | |
| 2 | Sand | 4 | | 16 | |
| 3 | Blue clay mixed with gravel | 43 | | 59 | |
| 4 | Sand gravel | 3 | | 62 | |
| 5 | Conglomerate limestone | 1 | | 63 | |
| 6 | Gray shale | 14 | | 77 | |
| 7 | Fossiliferous shale | 2 | | 79 | |
| 8 | Black shale | 3 | | 82 | |
| 9 | Coal | 1 | 9 | 83 | 9 |
| 10 | Clay shale | 16 | 3 | 100 | |
| 11 | Red lime shale mixture | 3 | | 103 | |
| 12 | Lime shale | 3 | | 106 | |
| 13 | Dark shale | 16 | | 122 | |
| 14 | Limestone | 1 | | 123 | |
| 15 | Black shale | 1 | 10 | 124 | 10 |
| 16 | Coal | | 2 | 125 | |
| 17 | Clay shale | 6 | | 131 | |
| 18 | Sand shale | 17 | | 148 | |
| 19 | Gray shale | 13 | | 161 | |
| 20 | Coal | | 6 | 161 | 6 |
| 21 | Clay shale | 1 | 6 | 163 | |
| 22 | Gray shale | 10 | | 173 | |
| 23 | Coal | | 6 | 173 | 6 |
| 24 | Soft gray shale | 5 | | 178 | 6 |
| 26 | Sandstone | 11 | 6 | 190 | |
| 27 | Gray shale | 19 | | 217 | |
| 28 | Clay shale | 4 | | 221 | |
| 29 | Sand shale | 38 | | 259 | |
| 30 | Black shale | 3 | | 262 | |
| 31 | Coal | 1 | 6 | 263 | 6 |
| 32 | Clay shale | 4 | 6 | 268 | |
| 33 | Lime shale | 5 | | 273 | |
| 34 | Sand shale | 17 | | 290 | |
| 35 | Gray shale | 27 | | 317 | |
| 36 | Dark shale | 12 | | 329 | 5 |
| 37 | Coal | | 5 | 329 | |
| 38 | Fire Clay | 4 | 7 | 334 | |
| 39 | Sand shale | 10 | | 344 | |
| 40 | Gray shale | 1 | | 335 | |
| 41 | Limestone | 2 | | 347 | |
| 42 | Lime shale | 3 | | 350 | |
| 43 | Limestone | 6 | | 356 | |
| 44 | Red and lime shale, mixed | 6 | | 362 | |
| 45 | Gray shale | 13 | | 375 | |
| 46 | Dark shale | 8 | | 383 | |
| 47 | Coal | | 8 | 383 | 8 |
| 48 | Clay shale | 3 | 4 | 387 | |
| 49 | Gray shale | 2 | | 389 | |
| 50 | Sand shale | 12 | | 401 | |
| 51 | Sandstone | 15 | | 416 | |
| 52 | Sandstone | 7 | | 423 | |
| 53 | Sand shale | 17 | | 440 | |
| 54 | Gray shale | 7 | 6 | 447 | 6 |
| 55 | Coal | 3 | 4 | 450 | 10 |
| 56 | Clay shale | 6 | 2 | 457 | |
| 57 | Sandstone | 12 | | 469 | |
| 58 | Sand shale | 7 | | 476 | |
| 59 | Dark shale with brown bands | 3 | | 479 | |
| 60 | Dark shale with brown bands | 5 | 5 | 484 | 5 |
| 61 | Coal | 3 | 10 | 488 | 3 |
| 62 | Clay shale | | 9 | 489 | |
| 63 | Limestone | 2 | | 491 | |
| 64 | Dark Shale | 7 | | 498 | |
| 65 | Coal | | 10 | 498 | 10 |
| 66 | Clay shale | 5 | 1 | 504 | |
| 67 | Lime stone | 2 | | 506 | |
| 68 | Dark shale | 1 | | 507 | |

*No. 2 Diamond Drill Hole*—Concluded.

| | | Thickness | | Depth. | |
|---|---|---|---|---|---|
| | | Feet. | Inches. | Feet. | Inches. |
| 69 | Sandstone | 6 | | 513 | |
| 70 | Sandstone | 8 | | 521 | |
| 71 | Gray shale | 8 | | 529 | |
| 72 | Dark shale | 6 | | 535 | |
| 73 | Black shale | 2 | | 537 | |
| 74 | Coal | 1 | 5 | 538 | 5 |
| 75 | Sand shale | 2 | 7 | 541 | |
| 76 | Sandstone | 4 | | 545 | |
| 77 | Sand shale | 1 | | 549 | |
| 78 | Dark shade | 1 | | 550 | |
| 79 | Limestone | 1 | | 551 | |
| 80 | Black shale | 1 | 6 | 552 | 6 |
| 81 | Coal | 3 | | 555 | 6 |
| 82 | Clay shale | 4 | 6 | 560 | |
| 83 | Lime shade | 12 | | 572 | |
| 84 | Sand shale | 27 | | 599 | |
| 85 | Gray shale | 45 | | 644 | |
| 86 | Dark shale, brown bands | 11 | | 655 | |
| 87 | Black shale | 5 | | 660 | |
| 88 | Coal | | 7 | 660 | 7 |
| 89 | Gray shale | | 3 | 660 | 10 |
| 90 | Coal | | 2 | 661 | |
| 91 | Gray shale | 9 | | 670 | |
| 92 | Sand | 16 | | 686 | |
| 93 | Sandstone | 18 | | 704 | |
| 94 | Sandstone, mixed coal seams | 2 | | 706 | |
| 95 | Sandstone | 11 | | 717 | |
| 96 | Sand shale | 1 | | 718 | |
| 97 | Sandstone | 13 | | 731 | |
| 98 | Coal mixed with sandstone | 1 | | 732 | |
| 99 | Dark shale | 2 | | 734 | |
| 100 | Black shale | 12 | | 746 | |
| 101 | Coal | 1 | 9 | 747 | 9 |
| 102 | Clay shale | 1 | 3 | 749 | |
| 103 | Gray shale | 13 | | 762 | |
| 104 | Sandstone | 5 | | 767 | |
| 105 | Gray shale | 9 | | 776 | |
| 106 | Coal | 7 | | 783 | |
| 107 | Clay shale | 5 | | 788 | |
| 108 | Gray shale | 21 | | 809 | |
| 109 | Dark limestone | 1 | | 810 | |
| 110 | Black shale | 2 | | 812 | |
| 111 | Coal | | 9 | 812 | 9 |
| 112 | Fire clay | 8 | 3 | 821 | |
| 113 | Gray shale | 6 | | 827 | |
| 114 | Black shale | 6 | | 833 | |
| 115 | Coal | 3 | | 836 | |
| 116 | Clay shale | 2 | | 838 | |
| 117 | Sandstone | 16 | | 854 | |
| 118 | Coal | 2 | | 856 | |
| 119 | Blue shale | 10 | | 866 | |
| 120 | Limestone | 4 | | 870 | |
| 121 | Sandstone | 2 | | 872 | |

## *No. 3 Diamond Drill Hole.*

| | | Thickness Feet. | Thickness Inches. | Depth Feet. | Depth Inches. |
|---|---|---|---|---|---|
| 1 | Surface | 2 | | 2 | |
| 2 | Sand and clay | 10 | | 12 | |
| 3 | Soft sandstone | 6 | | 18 | |
| 4 | Hard sandstone | 14 | | 32 | |
| 5 | Clay shale | 13 | | 45 | |
| 6 | Gray shale | 4 | | 49 | |
| 7 | Limestone | 3 | | 52 | |
| 8 | Black shale | 3 | | 55 | |
| 9 | Coal | 1 | | 56 | |
| 10 | Clay shale | 14 | | 70 | |
| 11 | Gray and red shale | 15 | | 85 | |
| 12 | Dark shale | 18 | | 103 | |
| 13 | Coal | | 5 | 103 | 5 |
| 14 | Clay shale | 4 | 7 | 108 | |
| 15 | Sand shale | 16 | | 124 | |
| 16 | Gray shale | 9 | 6 | 133 | 6 |
| 17 | Coal | | 6 | 134 | |
| 18 | Gray shale | 11 | | 145 | |
| 19 | Sand shale | 15 | | 160 | |
| 20 | Dark shale | 17 | | 177 | |
| 21 | Limestone | 1 | | 178 | |
| 22 | Gray shale | 2 | | 180 | |
| 23 | Lime shale | 8 | | 188 | |
| 24 | Sand shale | 38 | | 226 | |
| 25 | Black shale | 3 | | 229 | |
| 26 | Coal | 1 | | 230 | |
| 27 | Gray shale | 4 | | 234 | |
| 28 | Sand shale | 1 | | 235 | |
| 29 | Sandstone | 10 | | 245 | |
| 30 | Sand shale | 25 | | 270 | |
| 31 | Gray shale | 27 | | 297 | |
| 32 | Black shale | 3 | | 300 | |
| 33 | Coal | | 6 | 300 | 6 |
| 34 | Gray shale | 3 | 6 | 304 | |
| 35 | Lime shale | 1 | | 305 | |
| 36 | Dark shale | 11 | | 316 | |
| 37 | Limestone | 8 | | 324 | |
| 38 | Gray shale | 9 | | 333 | |
| 39 | Blue shale | 6 | | 339 | |
| 40 | Sand shale | 6 | | 345 | |
| 41 | Lime shale | 5 | | 350 | |
| 42 | Dark shale | 2 | | 352 | |
| 43 | Coal | | 2 | 352 | 2 |
| 44 | Clay shale | | 10 | 353 | |
| 45 | Sandstone | 17 | | 370 | |
| 46 | Sand shale | 37 | | 407 | |
| 47 | Gray shale | 12 | | 419 | |
| 48 | Coal | 3 | 4 | 422 | 4 |
| 49 | Clay shale | 3 | 8 | 426 | |
| 50 | Limestone | 5 | | 431 | |
| 51 | Dark shale | 2 | | 433 | |
| 52 | Lime shale | 1 | | 434 | |
| 53 | Limestone | 3 | | 437 | |
| 54 | Sand shale | 7 | | 444 | |
| 55 | Dark shale blue bands | 9 | | 453 | |
| 56 | Coal and clay shale mixed | 4 | | 457 | |
| 57 | Clay shale limestone bands | 9 | | 466 | |
| 58 | Coal | | 10 | 466 | 10 |
| 59 | Clay shale | 6 | 2 | 473 | |
| 60 | Sand shale | 21 | | 494 | |
| 61 | Dark shale brown bands | 10 | | 504 | |
| 62 | Coal | 2 | 6 | 506 | 6 |
| 63 | Clay shale | 5 | 6 | 512 | |
| 64 | Dark shale | 1 | | 513 | |
| 65 | Limestone | 4 | | 517 | |
| 66 | Dark shale | | 9 | 517 | 9 |
| 67 | Coal | 3 | 3 | 521 | |
| 68 | Clay shale | 6 | | 527 | |
| 69 | Sand shale | 13 | | 450 | |

*No. 3 Diamond Drill Hole*—Concluded.

| | | Thickness Feet. | Thickness Inches. | Depth Feet. | Depth Inches. |
|---|---|---|---|---|---|
| 70 | Sandstone | 10 | | 550 | |
| 71 | Sand shale | 8 | | 558 | |
| 72 | Gray shale | 58 | | 616 | |
| 73 | Dark shale brown bands | 8 | | 624 | |
| 74 | Limestone | 5 | | 629 | |
| 75 | Dark shale | 2 | | 631 | |
| 76 | Coal | 2 | | 633 | |
| 77 | Gray shale | 2 | | 635 | |
| 78 | Sand shale | 17 | | 652 | |
| 79 | Sandstone | 4 | | 656 | |
| 80 | Sand shale | 3 | | 659 | |
| 81 | Sandstone | 28 | | 687 | |
| 82 | Sandstone coal seams | 9 | | 696 | |
| 83 | Sandstone | 3 | | 699 | |
| 84 | Sandstone coal seams | 2 | | 701 | |
| 85 | Gray shale | 4 | | 705 | |
| 86 | Black shale | 9 | | 714 | |
| 87 | Coal | | 6 | 714 | [illegible] |
| 88 | Clay shale | 1 | 6 | 716 | |
| 89 | Sandstone | 3 | | 719 | |
| 90 | Gray shale | 5 | | 724 | |
| 91 | Sand shale | 8 | | 732 | |
| 92 | Gray shale | 5 | | 737 | |
| 93 | Sandstone | 2 | | 739 | |
| 94 | Gray shale | 8 | 6 | 747 | [illegible] |
| 95 | Coal | 8 | 6 | 756 | [illegible] |
| 96 | Clay shale | 1 | | 757 | |

*No. 4—The Delafield Coal Company's Borings.*

The Delafield Coal Company's prospect hole is located on the wes[illegible] half of the northeast quarter of section 34, T. 4 N., R. 5 W., Hamilto[illegible] county. The rocks penetrated in this hole are of Carboniferous ag[illegible] and all are included in the Pennsylvanian or coal measure series. Th[illegible] driller's log is as below:

| No. | Drillers' Log. | Thickness Feet. | Thickness Inches. | Depth Feet. |
|---|---|---|---|---|
| | *Recent and Pleistocene.* | | | |
| 1 | Surface material | 13 | | 13 |
| | *Coal Measures—Pennsylvanian.* | | | |
| 2 | Soft blue shale | 7 | 6 | 20 |
| 3 | Sandstone | 9 | 6 | 30 |
| 4 | Blue shale | 9 | 6 | 39 |
| 5 | Coal | | 10 | 40 |
| 6 | Fire clay | 3 | | 43 |
| 7 | Sandstone | 19 | 8 | 63 |
| 8 | Blue shale | 15 | | ...... |
| 9 | Blue shale | 51 | 6 | 129 |
| 10 | Sandstone | 10 | 6 | ...... |
| 11 | Sandstone | 23 | | 163 |
| 12 | Blue sand shale | 15 | | ...... |
| 13 | Blue sand shale | 30 | | 208 |
| 14 | Blue shale | 39 | | ...... |
| 15 | Blue shale | 23 | 6 | 270 |
| 16 | Coal | 1 | 2 | 271 |
| 17 | Blue shale | 1 | | 272 |
| 18 | Limestone | 10 | | 282 |

*No. 4*—Concluded.

| No. | Drillers' Log. | Thickness Feet. | Thickness Inches. | Depth Feet. | Depth Inches. |
|---|---|---|---|---|---|
| 19 | Blue shale | 17 | 4 | | |
| 20 | Dark shale | 5 | 5 | | |
| 21 | Blue shale | 1 | | 306 | 5 |
| 22 | Lime rock | 1 | | 307 | 5 |
| 23 | Black shale | 3 | 7 | 311 | |
| 24 | Blue shale | 19 | | | |
| 25 | Blue shale | 30 | | 350 | |
| 26 | Sandstone | 8 | | | |
| 27 | Sandstone | 35 | | | |
| 28 | Sandstone | 23 | 6 | 426 | 6 |
| 29 | Limestone | 5 | 6 | | |
| 30 | Limestone | 6 | | 438 | |
| 31 | Black slate | 3 | | | |
| 32 | Black slate | 3 | | 444 | |
| 33 | Blue sand shale | 10 | | 454 | 3 |
| 34 | Coal | | 3 | 454 | 3 |
| 35 | Fire clay | 3 | | 457 | 3 |
| 36 | Blue shale | 1 | | 458 | 3 |
| 37 | Sand shale with hard band | 20 | | | |
| 38 | Sand shale with hard band | 13 | | 491 | 3 |
| 39 | Sand shale | 12 | | | |
| 40 | Sand shale | 10 | | | |
| 41 | Sand shale | 20 | | | |
| 42 | Sand shale | 27 | | 560 | 3 |
| 43 | Blue shale | 12 | | | |
| 44 | Blue shale | 20 | | 592 | 3 |
| 45 | Light sand shale | 11 | | 603 | 3 |
| 46 | Coal | 1 | 4 | 609 | 7 |
| 47 | Light sand shale | 7 | | | |
| 48 | Sand shale | 20 | | 631 | 7 |
| 49 | Light shale | 8 | | | |
| 50 | Blue shale | 6 | 8 | 646 | 3 |
| 51 | Limestone | 2 | | 648 | 3 |
| 52 | Light shale | 4 | | 652 | 3 |
| 53 | Sandstone | 10 | | | |
| 54 | Sandstone | 7 | | 669 | 3 |
| 55 | Black shale | 2 | 6 | 671 | 9 |
| 56 | Coal | | 6 | 672 | 3 |
| 57 | Light shale, soft | 10 | | 682 | 3 |
| 58 | Limestone | 1 | | 683 | 3 |
| 59 | Sandstone | 3 | | 686 | 3 |
| 60 | Sandstone | 12 | | | |
| 61 | Sandstone | 15 | | | |
| 62 | Sandstone | 30 | | 743 | 3 |
| 63 | Sand shale | 6 | | 749 | 3 |
| 64 | Blue shale | 10 | | | |
| 65 | Blue shale | 29 | | 788 | 3 |
| 66 | Black slate | 2 | | 190 | 3 |
| 67 | Coal | | 6 | 790 | 3 |
| 68 | Sandstone | 4 | | 794 | 9 |
| 69 | Limestone | 1 | 8 | | |
| 70 | Soft limestone | 3 | | 799 | 5 |
| 71 | Black slate | 1 | | 800 | 5 |
| 72 | Coal | 1 | | 801 | 5 |
| 73 | Fire clay | 2 | | 803 | 5 |
| 74 | Light shale | 7 | 11 | 811 | 4 |
| 75 | Limestone | 8 | | 819 | 4 |
| 76 | Black slate | 2 | | | |
| 77 | Light slate | 10 | | | |
| 78 | Light slate | 8 | | | |
| 79 | Blue slate | 5 | | 844 | 4 |
| 80 | Coal | 2 | | 846 | 4 |
| 81 | Sand shale | 5 | | | |
| 82 | Sand shale | 17 | | 868 | 4 |
| 83 | Limestone | 3 | | | |
| 84 | Limestone | 3 | | 874 | 4 |
| 85 | Blue shale | 2 | | 876 | 4 |
| 86 | Sand shale | 12 | 6 | 888 | 10 |
| 87 | Sand shale | 2 | | 907 | 4 |
| 88 | Sand shale | 16 | 6 | | |
| 89 | Soft black shale | | 6 | | |
| 90 | Dark blue shale | 2 | | 909 | 10 |
| 91 | Blue limestone | 4 | | 913 | 10 |
| 92 | Coal-limestone | 5 | 3 | 919 | 1 |
| 93 | Fire clay | | 9 | 919 | 10 |

## *No. 5—Robinson Well Record.*

| No. | Strata. | Thickness. Feet. | Depth. Feet. |
|---|---|---|---|
| 1 | Soil | 2 | ........... |
| 2 | Clay and sand | 8 | 10 |
| 3 | Sandstone | 12 | 22 |
| 4 | Shale (soapstone) | 42 | 64 |
| 5 | Coal and black shale | 2 | 66 |
| 6 | Underclay (gray shale) | 4 | 70 |
| 7 | Limestone | 15 | 65 |
| 8 | Shale | 25 | 110 |
| 9 | Water, sand | 10 | 120 |
| 10 | Gray shale | 18 | 138 |
| 11 | Dark Shale (slate) | 37 | 175 |
| 12 | Light shale | 15 | 190 |
| 13 | Reddish shale | 10 | 200 |
| 14 | Light shale | 8 | 208 |
| 15 | Dark shale | 12 | 220 |
| 16 | Light sand rock | 8 | 228 |
| 17 | White shale (clay) | 17 | 245 |
| 18 | Dark shale | 16 | 261 |
| 19 | Light shale | 14 | 275 |
| 20 | Sandstone (rock sand) | 40 | 315 |
| 21 | Brown shale | 30 | 345 |
| 22 | Black shale | 5 | 350 |
| 23 | Light shale | 20 | 370 |
| 24 | Brown shale | 25 | 395 |
| 25 | Dark slate | 7 | 402 |
| 26 | Dark lime | 6 | 408 |
| 27 | Light shale | 22 | 430 |
| 28 | Hard lime rock | 7 | 437 |
| 29 | Dark brown shale | 10 | 447 |
| 30 | Light shale | 43 | 490 |
| 31 | Dark shale | 43 | 532 |
| 32 | Coal | 4 | 536 |
| 33 | Fire clay (light shale) | 8 | 544 |
| 34 | Lime rock | 5 | 549 |
| 35 | Shale | 8 | 557 |
| 36 | Sandstone | 18 | 575 |
| 37 | Coal | 2 | 577 |
| 38 | Fire clay (rock) | 5 | 282 |
| 39 | Slate | 10 | 592 |
| 40 | Shale | 8 | 600 |
| 41 | Sandstone | 27 | 627 |
| 42 | Shale | 8 | 635 |
| 43 | Hard rock | 4 | 639 |
| 44 | Coal | 2 | 641 |
| 45 | Fire clay | 15 | 656 |
| 46 | Sandstone | 10 | 666 |
| 47 | Shale | 44 | 710 |
| 48 | Sandstone | 30 | 740 |
| 49 | Brown shale | 10 | 740 |
| 50 | Gray shale | 40 | 790 |
| 51 | Black shale | 40 | 830 |
| 52 | Water sand (salt water) | 40 | 870 |
| 53 | Dark shale | 35 | 905 |
| 54 | Shale | 55 | 960 |
| 55 | Sandy shale (first gas) | 10 | 970 |
| 56 | Shale | 30 | 1,000 |
| 57 | Sand rock, white to brown | 35 | 1,035 |
| 58 | Shale | 10 | 1,045 |
| 59 | Sandstone | 72 | 1,117 |
| 60 | Dark shale with 16 inch vein of coal | 7 | 1,124 |
| 61 | Sandstone and sandy shale | 40 | 1,164 |
| 62 | Brown sand | 10 | 1.174 |
| 63 | Sandstone (second gas) | 12 | 1,186 |
| 64 | Sandstone | 22 | 1.208 |
| 65 | Shale | 17 | 1,225 |
| 66 | Limestone and shells | 65 | 1,290 |
| 67 | Limestone, hard, dark gray, crystalline | 40 | 1,330 |

## *No. 6. Lawrence County Record.*

| No. | Strata. | Thickness. Feet. | Depth. Feet. |
|---|---|---|---|
| 1 | Conductor | 12 | 12 |
| 2 | Lime and sand | 24 | 36 |
| 3 | Slate | 61 | 97 |
| 4 | Slate and lime | 43 | 140 |
| 5 | Slate | 90 | 230 |
| 6 | Sand | 16 | 245 |
| 7 | Slate | 15 | 260 |
| 8 | Sand | 54 | 314 |
| 9 | Slate | 131 | 445 |
| 10 | Lime | 10 | 455 |
| 11 | Slate | 200 | 655 |
| 12 | Lime | 5 | 660 |
| 13 | Slate and shell | 110 | 770 |
| 14 | Sand and water | 35 | 805 |
| 15 | Slate | 95 | 900 |
| 16 | Upper Bridgeport sand | 25 | 925 |
| 17 | Slate and shell | 150 | 1,075 |
| 18 | Sand | 10 | 1,085 |
| 19 | Slate | 25 | 1,120 |
| 20 | Sand and water | 25 | 16145 |
| 21 | Slate | 85 | 1,235 |
| 22 | Slate and sand showing of oil and gas Buchanan sand | 5 | 1,340 |
| 23 | Sand | 70 | 1,410 |
| 24 | ..do | 60 | 1,470 |
| 25 | Lime | 20 | 1,490 |
| 26 | Slate | 10 | 1,500 |
| 27 | Blue and black slate | 25 | 1,525 |
| 28 | Blue and black sand | 10 | 1,535 |
| 29 | Red rock | 8 | 1,543 |
| 30 | Very hard lime | 12 | 1,555 |
| 31 | Slate break | 5 | 1,560 |
| 32 | Very hard lime | 20 | 1,580 |
| 33 | Slate | 40 | 1,620 |
| 34 | Lime | 20 | 1,640 |
| 35 | Black slate | 40 | 1,680 |
| 36 | Top of oil sand | | 1,680 |
| 37 | Bottom of oil sand | 50 | 1,730 |

*No. 7 Wabash County Record.*

| No. | Strata. | Thickness. Feet. | Depth. Feet. |
|---|---|---|---|
| 1 | Soil | 7 | 7 |
| 2 | Sandstone | 10 | 17 |
| 3 | Shale | 7 | 24 |
| 4 | Friendsville coal | 3 | 27 |
| 5 | Shale | 25 | 52 |
| 6 | Limestone | 20 | 72 |
| 7 | Shale | 15 | 87 |
| 8 | Limestone | 3 | 90 |
| 9 | Shale | 70 | 160 |
| 10 | Sandstone | 75 | 235 |
| 11 | Shale | 105 | 340 |
| 12 | Sandstone | 20 | 360 |
| 13 | Shale | 49 | 400 |
| 14 | Limestone | 12 | 412 |
| 15 | Red shale | 12 | 424 |
| 16 | Limestone | 16 | 440 |
| 17 | Shale | 160 | 600 |
| 18 | Sandstone | 12 | 612 |
| 19 | Shale | 18 | 630 |
| 20 | Limestone | 3 | 633 |
| 21 | Shale | 27 | 660 |
| 22 | Sandstone | 120 | 780 |
| 23 | Coal | 1 | 781 |
| 24 | Shale | 41 | 822 |
| 25 | Sandstone | 38 | 860 |
| 26 | Shale | 6 | 866 |
| 27 | Sandstone | 61 | 927 |
| 28 | Shale | 5 | 932 |
| 29 | Sandstone | 52 | 984 |
| 30 | Coal (gas) | ½ | 984½ |
| 31 | Shale | 47 | 1,031 |
| 32 | Sandstone | 38 | 1,069 |
| 33 | Shale | 29 | 1,098 |
| 34 | Limestone | 12 | 1,110 |
| 35 | Shale | 106 | 1,216 |
| 36 | Coal | ½ | 1,216½ |
| 37 | Limestone | 6 | 1,222 |
| 38 | Shale | 238 | 1,460 |
| 39 | Sandstone | 37 | 1,497 |
| 40 | Shale | 88 | 1,585 |
| 41 | Limestone | 10 | 1,595 |
| 42 | Shale | 107 | 1,702 |
| 43 | Limestone | 1 | 1,703 |
| 44 | Shale | 19 | 1,722 |
| 45 | Sandstone | 83 | 1,805 |
| 46 | Shale | 17 | 1,822 |
| 47 | Sandstone | 5 | 1,827 |

A little study of these records will show that there is a marked change in the character of the strata from point to point, and if their exact elevation were known, considerable irregularities in the altitude of equivalent beds would appear. The following tentative correlations may be suggested. No. 38 of the Gillespie record is probably to be correlated with Nos. 41 to 44 of record No. 2 and Nos. 35 to 37 of record No. 3. No. 81 of record No. 2, No. 67 of record No. 3 and No. 92 of record No. 4 seem to represent the same coal bed. This is probably also the coal at 641 feet (No. 44) in record No. 5, Nos. 26 to 28 corresponding to Nos. 41 to 44 of record No. 2. In record No. 6 the Upper Bridgeport sand, No. 16, is correlated with the Robinson sand No. 55 of record No. 5, while the beds from No. 29 down represent the Chester group, presumably to be correlated with No. 34 and lower horizons of record No. 7. While there is some doubt as to

these correlations they afford on the whole a consistent and satisfactory view of the data at hand. The presence of a thick body of strata, consisting mainly of sand between characteristic coal measures above and the alternating limestones, sandstones and shales of the Chester below, is well brought out. These beds correspond to the Pottsville group and contain the horizons so far found to be most productive.

*Coal Measure Sands*—The character of the lower coal measure beds is discussed elsewhere in this volume by F. W. DeWolf, and is illustrated graphically in figure 29, reproduced by the courtesy of the U. S. Geological Survey. It will be noted by examining this figure and the drill records already quoted that sandstones and sandy shales occur at a number of different horizons throughout the section, and it seems impossible, with present data, to make definite correlations. The more persistent members of the section are certain coal beds, particularly the group including No. 5 and No. 7 of local nomenclature. It is probable that a careful use of these horizons will ultimately permit the working out of the structure of the rocks in the oil region as is already being done in the coal area to the south and west.

*Pottsville Sands*—The rocks in Illinois which are the approximate equivalents of the Pottsville of the east have been but little studied. In the older reports they were usually referred to as the millstone grit, conglomerate measures, and occasionally as the Ferruginous sandstone.*

In Indiana they have been called the Mansfield sandstones.† Mr. David White has recently made a reconnoisance over much of the area within which they outcrop, and has the following to say regarding the correlation of the beds.§

"The Morris, or 'No. 2,' coal of Illinois lies probably at or near the horizon of the Lower Kittanning coal of Pennsylvania. Such brief examinations as I was able to make in the regions in which 'coal No. 1' is supposed to be exploited are interesting or important chiefly for the discrepancies discovered in the prevailing correlation and nomenclature of the coals. The evidence obtained at several points in Rock Island county goes to show that the refractory fire clay mined along the Mississippi river in this region belongs in the Upper Pottsville, and not far from the level of the Sharon coal. It is the horizon of most abundant *Megalopteris*. The adjacent Muscatine sandstone which falls at an approximate paleobotanical level, in the Upper Pottsville, is the source of the *Lesleya grandis*, described as having been derived from the Chester. The plants, which I had time to collect only in insufficient quantity, from the roof of 'coal No. 1' in this county are clearly of Pottsville age, and lie, perhaps, within the limits of the Connoquenessing sandstones (Upper Pottsville) of the Appalachian trough. Additional material is needed that a considerable interval elapsed between the deposition of this coal and that of 'No. 2' in Grundy county.

"The attempt to secure palebotanical material from the coal regarded as 'No. 1,' in Scott county, was largely unsuccessful, possibly

*Worthen: Geological Survey, Illinois. Vol. 1, p. 48.
†Hopkins, T. C., Dept. Geol. Nat. Res. (Indiana). 23d Ann. Rept., p. 95, et seq.
‡State Geol. Surv. (Illinois) Bulletin 4, pp. 201-202.

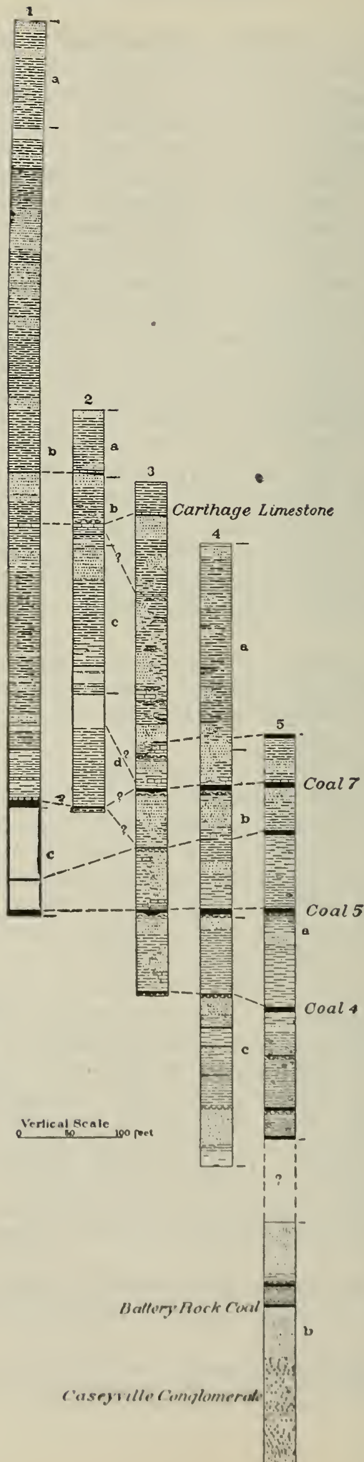



FIG. 29. Representative columnar sections of the coal measures of Southern Illinois. Compiled by F. W. DeWolf, (see p. 215.)

on account of lack of time; but the shales over the supposed representative of this bed in the deep mine at Litchfield furnishes a flora perhaps not older than that of the Mercer group, or uppermost Pottsville. This is the most surprising in view of the fact that in the southeastern portion of the coal field, at Battery Rock, Hardin county, the coal known as 'No. 1' in the State reports lies about one hundred feet below a coal shown by its flora to be, probably, of Lower Pottsville age. In short, it appears that in southeastern Illinois there were deposited representatives of the Lookout formation, of Lower Pottsville age, and a portion, at least, of the Middle Pottsville, prior to the deposition of the earliest Upper Carboniferous sediments in the northwestern portion of the State. It is probable that these, the oldest of the Illinois coal measures, were laid down when the basin was greatly restricted, and included only a small part of the present coal field. The deposition of the 'No. 1 coal' of the northern part of the State was possibly only after a considerable subsidence of the deeper portions of the basin. No less than four coals were laid down in Hardin county before the formation of the deep coal at Litchfield, and three, at least, of these coals antedated the so-called 'No. 1' seam of Rock Island county. Time was not available for the collection of the fossils necessary to the definite correlation of the older coal horizons in the southern region though they will be tentatively brought within certain limits when the collections now in hand have been studied."

In the northern and western part of the State these beds are quite thin, and over the central part they are believed to be absent. To the south they thicken rapidly, becoming 500 feet or more thick. In general, the formation may be regarded as a wedge thinning to a northern outcropping edge, now buried under the coal measures. North of Charleston and Litchfield the thickness of this formation is evidently inconsiderable, and this is of importance in view of the fact that it is in it that the Buchanan and possibly the Robinson-Bridgeport sands occur, as well probably as the sands which at Litchfield and vicinity have yielded gas and oil.

*Chester Sands*—As has already been indicated, the Chester group has proven oil bearing in Southern Indiana, and in both southwestern and southeastern Illinois. The Everson drill record (No. 6) already quoted illustrates its character, so far as penetrated in the oil district. In Indiana, oil is produced at Princeton in Gibson* county, from the Huron sandstone, which belongs in this group. The oil is found in a bluish gray, sharp-grained sandstone, at an average depth of 890 feet and about 40 feet below the top of the sand.† The formation is composed of three beds of limestone with two intervening beds of sandstone, their combined thickness reading a total of 150 feet.§ It seems to thicken to the west, as is shown by the Lawrence county and Wabash county drill records already quoted. Detailed correlations are at present impossible, and there is no very positive basis for the recognition of the formation in drill records except the presence of alternating limestones, and sandstones below the heavy sandstones

* Blatchley, Raymond, Dept. Geol. Nat. Res. (Indiana) 31st Ann. Rept., pp. 559-593.
† Blatchley, W. S., Dept. Geol. Nat. Res. (Indiana) 30th Ann. Rept., p. 1183.
§ Blatchley, W. S., Dept. Geol. Nat. Res. (Indiana) 28th Ann. Rept., p. 202.

of Pottsville age, and above the heavy Cypress sandstone which in turn rests on heavy limestones usually more or less cherty. Red shales seem also to be frequently found in the Chester in the wells, as they do in outcrops in the southern part of the State. In the western part of Illinois the Chester is well exposed and has been carefully studied by Weller. His description may be quoted as follows:

"From most of the literature on the subject one gains the impression that the Chester is dominantly a limestone formation, but in working over the area occupied by the beds in the field, one is impressed with the fact that it is in a large part sandstone. Nowhere in that part of Illinois occupied by these beds, is the limestone element in the formation the most conspicuous feature, except along the Mississippi river bluffs above Chester, from that city to the point where the Cypress sandstone outcrop begins. It is probable that where the limestone has its greatest development, not more than one-third of the total thickness is calcareous, and over a large part of the area the thickness of the limestones probably does not exceed one-fifth of the entire thickness.

"The best region in which to study the succession of beds in the Chester, is in the Mississippi river bluffs above and below the city of Chester. This section shows an alternation of chiefly calcareous and arenaceous formations, there being three conspicuous limestones and three sandstones. The limestones are frequently interbedded with carcareous shales, and the sandstones frequently become arenaceous shales or at times clay shales.

"The lowest member of the "group," above the Cypress sandstone. is a limestone and shale formation attaining a maximum thickness of approximately 250 feet at and above Chester. In its lower portion it includes considerable beds of calcareous and clay shales, a bed of variegated red and blue shale being commonly present near the base. In the upper part of this member is a great limestone ledge about 100 feet in thickness, with occasional thin shaly partings, which furnishes the quarry rock at the Southern Illinois Penitentiary, at Menard. The great mass of the fauna of the "Chester group" in Illinois has been described from this lower, calcareous member of the formation as a whole.

"The second member of the 'group' is a sandstone or shale, the shale being most conspicuous in the more northern part of the area. while to the south it is almost wholly a sandstone similar to the Cypress in character, but usually thinner bedded and not infrequently more or less of an arenaceous shale. This division attains a thickness of about 80 feet. The third is again a limestone which is apparently more impure than most of the beds of the lower division. It is much less fossiliferous than the lower division and the fossils are such as to give it definite faunal characters which can be recognized over wide areas. Its thickness near Chester is about 60 feet. The fourth member is again a sandstone similar to the earlier sandstone beds, and attains a thickness of 65 feet. The fifth member is a limestone similar to limestone No. 2, in lithologic characters, and is usually almost or quite unfossiliferous. Its thickness is about 35 feet. Following the third

limestone is another great sandstone member 100 feet or more in thickness, which is finely exposed back of the village of Rockwood in Randolph county.

"It seems to be altogether probable that these three limestone beds of the Chester 'group' can be differentiated and mapped throughout the faulted area in the southern part of the State, and by means of them the structure worked out in much detail. In the final work upon these beds it will probably be found to be expedient to distinguish each of these six members of the Chester by distinct formation names, just as the Cypress sandstone is now distinguished."

It is probable that the sandstone seen at Rockwood and here put in the Chester is really of Pottsville age. Excluding it and summarizing the description the general section would be as follows:

*General Section of the Chester.*

| | | Thickness. |
|---|---|---|
| 6 | Limestone | 35 |
| 5 | Sandstone | 65 |
| 4 | Limestone | 60 |
| 3 | Sandstone and shale | 80 |
| 2 | Limestone | 100 |
| 1 | Shale and shalystone with red shales in lower part | 150 |

At Sparta, where for many years this formation yielded gas and where more recently oil has also been found, a number of well records have been published by J. M. Nickles.* He constructed the following general section, based upon well records and the reports of the Worthen Survey.

*Nickles General Section at Sparta.*

| No. | | Thickness Feet. |
|---|---|---|
| 1 | Soil and drift, about | 40 |
| 2 | Sandstone, at top more or less decomposed | 30 |
| 3 | Limestone | 10 |
| 4 | Coal (No. 7) | 2 |
| 5 | Fire clay and shale | 15 |
| 6 | Limestone, with shale partings | 22 |
| 7 | Shale | 0-3 |
| 8 | Coal (No. 6) | 6 |
| 9 | Fire clay and shale | 6 |
| 10 | Limestone | 8 |
| 11 | Shale | 4 |
| 12 | Coal (No. 5) | 4 |
| 13 | Shale | 8 |
| 14 | Limestone, with shale partings | 16 |
| 15 | Shale | 14 |
| 16 | Coal (No. 3?) | 2-4 |
| 17 | Shale | 35 |
| 18 | Coal (No. 2?) | 3 |
| 19 | Sandstone and shale (conglomerate) | 180 |
| 20 | Limestone (No. 1 of Chester group) | 20 |
| 21 | Shale | 15 |
| 22 | Sandstone | 40 |
| 23 | Shale | 17 |
| 24 | Limestone (No. 2 of Chester group) | 15 |
| 25 | Shale | 20 |
| 26 | Sandstone | 40 |
| 27 | Shale | 18 |
| 28 | Limestone (No. 3 of Chester group) | 30 |
| 29 | Soft shale (Lyropora shale) | 65 |
| 30 | Limestone (No. 4 of Chester group) | 30 |
| 31 | Sandstone | 30 |
| 32 | Shale and limestone | 30 |
| 33 | Shale | 15 |
| 34 | Sandstone (gas) | 7 |
| 35 | Shale | 20 |
| 36 | Limestone | 14 |
| 37 | Shale | 40 |
| 38 | Sandstone and sandy shale (Aux Vases sandstone) | 120 |
| | Total thickness | 996 |

"Nos. 2-19 are coal measures, No. 19 being the basal sandstone (Conglomerate). Nos. 20-38 represents the entire thickness of the Chester Group, which, in this section, is made 636 feet. Prof. Worthen's section, referred to before, gives 613 feet.

*Rept. Ill. Board World's Fair Commission, pp. 198-199, 1893.

The Aux Vases sandstone noted here corresponds to the Cypress of later usage. His coal and limestone members refer to the corresponding coals and limestones of the Worthen general section of this region. A short distance north of here the coal measures rest directly on the St. Louis limestone, all of the Chester and most if not all of the Pottsville being absent. In the territory east and north of St. Louis remnants of Chester seem to be present under the coal measures, but the formation is thin and discontinuous so that the productive portion of the Chester as well as the Pottsville is to be thought of as a wedge-shaped mass with its thin edge to the north. The exact location of this edge can not be certainly given.

*Pre-Chester Sands*—Below the Chester, as the term is here used, there are no beds in the Carboniferous which are known to carry oil or gas in commercial quantities, though the rocks have been very little prospected. From its close association with the Chester proper, its wide extent and porous character the Cypress sandstone is looked upon as holding out some promise. Below that, in the Carboniferous, there are no known beds that are either encouraging or discouraging if a possible exception be made of the petroleum found in the geode bed of the Keokuk. This is not believed, however, to be especially significant.

### PRE-CARBONIFEROUS OIL BEARING ROCKS.

In the southern portion of the State pre-Carboniferous rocks are generally so deeply buried that they are believed to be, for the present beyond the practicable limit for prospecting. In addition the areas in which they outcrop are broken by faulting and it is thought that if they contained any considerable amount of gas or oil originally much of it would have escaped. The faulting also interferes, in advance of detailed stratigraphic work, with making the structural studies which should guide prospecting in these rocks. It may be noted in passing that the Trenton rock of southern Illinois is not dolomite as in the Indiana oil fields, and the Clinton, while somewhat like that of Ohio, is, so far as known, of only limited extent.

If, therefore, it be desired to prospect the lower formations it is suggested that for the present attention be directed to the northern and western parts of the State. In these regions the Devonian is generally thin or absent, but both the Niagara and the Galena-Trenton are present in considerable thickness. Lithologically, both formations are here favorable to oil accumulation, being porous dolomites. Over much of the area they are under satisfactory cover; the shales of the coal measures or of the Kinderhook in one case and of the Cincinnatian in the other. Furthermore, both the Niagara and the Galena-Trenton freequently show oil seepage along their outcrop, and enough is known to indicate that structural conditions are, in places, favorable. Indeed one small anticline in Pike county has already been found to yield gas from the Niagara in commercial quantities.* It should be

*Savage, T. E., Pike County Gas Field, Ill. State Geol. Surv., Bull. 2, pp. 77-78.

remembered, however, that over much of the area both formations have been pierced by wells driven to the underlying St. Peters sandstone for the artesian water which the latter contains, without discovering any noticeable amount of gas or oil. While it is entirely true that in drilling for water, beds containing commercial quantities of oil may be passed through and overlooked, it is probable that any large quantity of oil, and certainly any high pressure of gas would have been noticed. The relation of both the Niagara and the Galena-Trenton to underground water have not been thoroughly worked out.

## Correlation of Illinois Oil and Gas Bearing Rocks.

While it would be premature at this time to make definite correlations of the oil and gas sands of Illinois with those of other states, it will doubtless be helpful to some to indicate in a general way their approximate equivalents.

J. A. Bownocker gives the following table of oil and gas rocks in Ohio:*

*The Principal Divisions of the Geological Scale in Ohio, and the Oil and Gas Bearing Members.*

| | | | |
|---|---|---|---|
| Carboniferous | Coal measures | Goose Run sand | |
| | | Mitchell sand | |
| | | First Cow Run sand | |
| | | Macksburg 500-foot sand | |
| | | Second Cow Run sand | |
| | | Pottsville conglomerate | Salt sand |
| | | | Maxton sand |
| | Lower Carboniferous | Maxville limestone | Mountain lime |
| | | Logan group | Keener sand |
| | | | Big Injun sand |
| | | | Squaw sand |
| | | Berea grit | |
| Devonian | | | Ohio shales |
| Silurian | | | Lower Helderberg sand |
| | | | Clinton sand |
| Ordovician | | | Trenton limestone |

He also gives the following more detailed section, showing the Carboniferous oil and gas sands:†

| | |
|---|---|
| Dunkard formation, or upper barren coal measures, 500 feet | No oil or gas rocks |
| Monongahela formation, or upper productive coal measures, 200 feet | Goose Run sand |
| | 100 feet (interval.) |
| | Pittsburg or No. 8 coal |
| Conemaugh formation, or lower barren coal measures, 500 feet | 90 feet (interval.) |
| | Mitchell sand |
| | 200 feet (interval) |
| | First Cow Run sand |
| | Cambridge limestone |
| | Mahoning sandstone |
| Alleghney formation, or lower productive coal measures, 250 feet | Upper Freeport or No. 7 coal |
| | Dunkard or 300-sand = ? |
| | Freeport sandstone |
| | 50-foot (interval) |
| Conglomerate coal measures, 250 feet | Macksburg 500-foot sand = ? |
| | Tionesta sandstone |
| | 70 feet (interval) |
| | Second Cow Run sand = ? Massillion sandstone |
| | Sharon or No. 1 coal |

* Geol. Surv. Ohio, 4th Ser., Bull. 1, p. 17.
† Loc. Cit. p. 30.

The correlation of the lower coal measures of Illinois with those of Pennsylvania has been tentatively made by David White as below:*

"Good fossil plants, especially fossil ferns which are of greatest correlative value, are in general so rare in the shales immediately overlying the higher coals now mined at the localities visited in the State that but little material was gathered from this part of the coal measures in the course of my work, and these from but two or three points. From the field examination of these scanty collections I am disposed tentatively to regard 'coal No. 6' as probably belonging to the Freeport group of the Pennsylvania series. Hence the section including the Morris 'No. 2' coal and the 'No. 6' coal appears to fall within the Alleghany Series, or 'Lower Productive Measure' of Pennsylvania."

On this basis and assuming the Robinson-Bridgeport sand to be below the No. 2 coal, or its equivalent, a point open to some question, it will be seen that the Casey or Westfield sand is a correlative of the First Cow Run sand and the Bridgeport-Robinson sand the approximate correlative of the Macksburg. The Buchanon is the possible equivalent of the Second Cow Run. The Sparta-Kirkwood sands may correspond to the sands of the Logan group. It should be urged again, however, that these correlations are of the most meagre value and should not be accepted as of more than most general significance.

It may be further noted that the productive sands of southeastern Illinois are all distinctly younger than the oil bearing rocks of Indiana, and are not to be correlated with them except as the Kirkwood sand corresponds to that at Princeton, Indiana.

To the west a general correspondence between the oil sands of the Illinois and the Mid-Continental field may be made out in that both occur in the Pennsylvania rocks, and the most productive horizons are near the base.

The correlation of the pre-Carboniferous rocks which show oil seepage are sufficiently indicated by their names Niagaran and Trenton.

## KNOWN OIL POOLS OF SOUTHERN ILLINOIS.

The oil pools of Clark and Cumberland counties were discussed in some detail by W. S. Blatchley in 1906.* At that time but a few wells had been brought in Crawford county and none in Lawrence. Such data as were then available were given by him, and the reader should refer to that report for additional information. It is not the intention at this time to discuss in equivalent detail the whole area. The following brief summary, however, of the recognized distribution of the various sands may be of general interest.

In the northern or Casey district it is common to recognize three pools. The first is known variously as the Shallow Sand, Westfield, or Parker township pool, and is the one which was first developed. It includes the area north of Casey indicated as oil producing on the accompanying map (plate 21). It was very fully discussed in Blatchley's report of 1906 and the Gillespie well record already quoted shows

*State Geol. Surv. Ill., Bull. 4, p. 202.
†State Geol. Surv., Ill., Bull. 2.

the general character of the rocks. The oil is found at a depth of 325 to 400 feet, in part in a limestone already discussed and in part in a sandstone or sandy shale found above the main limestone. The best marker in this field is an upper limestone accompanied in places by red shale. In the Gillespie well this is 300 feet above the principal oil horizon and 380 below the lower limestone. This upper limestone outcrops along the streams south of Casey and is known as the Quarry Creek limestone. There is also a thick coal whose presence in the sections should be noted, and an upper oil sand not commonly very productive. For further details the reader is referred to Blatchley's report.

The second pool is that lying northwest of Casey and extending into Cumberland county. The sand mainly developed here probably corresponds to the upper one found in the Parker township pool. On the Goodman, Queen and other leases a second sand has been found deeper. Possibly this corresponds to the original sand of Parker township.

The third pool is in Johnson township southeast of Casey. Ordinarily but one sand is worked here at a depth of 430 feet, but on the Brant farm a second pay has been found 200 feet deeper. This shows a lighter oil. The Johnson township field includes a number of gas wells which supply Casey and Martinsville.

Various attempts have been made to find lower pay sands, but without great success. In one of the original bore holes put down by J. J. Hoblitzel, a showing of oil was reported at 1400 feet. The Pure Oil Company, however, put down a hole to a depth of 2200 feet in section 15 of Johnson township without important results other than a little gas at 1850 feet. Drillings from 1960 feet down examined at the Survey office showed only heavy limestone, in part cherty and indicate that the limestone below the Chester had been encountered. The record above this was too incomplete for satisfactory correlation.

In Crawford county three pools are recognized. These include the Oblong, Honey Creek and Duncanville pools. In all of them the oil is found at about the same depth, 900 feet, and it is common to speak of it as one sand though there are numerous barren spots and in many of the wells there are really two sands separated by 15 to 75 feet of black shale. Above the main productive sands others are encountered which frequently show gas or small amounts of oil. In one Honey Creek township well, for example, gas was found at 300 feet, an oil sand at 600 feet, another at 930 feet, but the main production was below black shale at 977 feet. The stratigraphic relations of these upper sands to those of Clark county are not definitely known.

The small pool found near Duncanville, while in about the same sands as the larger pools, shows oil of a much lower grade which is sold for fuel purposes only.

In Lawrence county there are three marked sands. The first is the Bridgeport sand which is found at about the same depth as the Robinson sand of Crawford county. It may none the less be a slightly lower sand owing to differences in elevation and to dip. It occurs at 900 feet. The second sand is the Buchanon found at about 1300 feet in and around Bridgeport. It is a coarse-grained, thick and very pro-

ductive sand. The lowest sand so far discovered is the Kirkwood, which is found at a depth of 1600 to 1700 feet and, as already indicated, is in the Chester formation.

## OIL AND GAS IN THE WESTERN PART OF THE STATE.

### INTRODUCTION.

Both oil and gas have been found in commercial quantities in the western part of the State. For several years oil was pumped regularly at Litchfield in Montgomery county, and gas has been used at Sparta in Randolph and Pittsfield in Pike counties. All three occurrences have been somewhat fully described in print, but as prospecting is now active in this area, and for the benefit of those to whom the older literature is not available, portions of the older reports are reproduced. It may be added that recent drilling has discovered some gas at Medora in Macoupin county and some oil near Hillsboro and Edwardsville. It is also reliably reported that small oil wells have been brought in in St. Louis and vicinity. In undertaking prospecting in this region it should be remembered that over most of the area north of Sparta the Chester is absent and over most of it the Pottsville beds are also absent or thin. The structure of a portion of the field is discussed in other pages of this report by J. A. Udden and F. W. DeWolf. (Pages 246-254.) There is an important structural terrace near DuQuoin which has not yet been tested for oil.

### RANDOLPH COUNTY.

J. M. Nickles, in the report already cited,* gives the following notes, briefly condensed, and tables of wells. The original article is accompanied by a small sketch map not reproduced here.

*Brief History*—A period of depression had fallen upon Sparta and the adjacent country. Something must be done to pull out from the slough of despondency into which all things had fallen. To Mr. W. B. Taylor was due the suggestion which led to the formation of a stock company, in December, 1887, to bore into the earth. The drill was started January 28, 1888, in the west end of the city of Sparta. Various delays and ill luck attended the driller, but at length on the eighth of June, at a depth from the surface of 845 feet, most unexpectedly, gas with strong pressure and in large volumes burst forth. The discovery was as grateful as it was unexpected. For a time, in the absence of any means of holding it in or utilizing it, the gas was suffered to flow out unchecked, and many millions of feet went to waste. Meanwhile, the large burning flame, twenty feet in height, aroused the surrounding country to a wonderful degree. But soon mains were laid, and the citizens were industriously piping their houses and putting gas burners into their stoves, and proceeded to enjoy nature's most impressive gift to man. Exploitation continued with the degree of success usually attending the drill. A second well, one-half mile west of the first, gave no gas. A third well, one-half mile distant, in a southeasterly direction, gave an abundant supply. And now the usual cupidity came into play with the attendant wastefulness. An adjoining landowner put down a well as near No. 3 as he could get. Of course it was successful, but as it was draining the same territory it simply decreased the life of its predecessor. The following table shows the continuation of the exploitation.

*Report Illinois Board World's Fair Commissioners, 1893, pp. 183-198.

*Table Showing Exploitation.*

| Number of well. | When bored. | Result. | Present condition. |
|---|---|---|---|
| 1 | Jan -June, 1888........ | Strong flow of gas.................. | Produced but little after 1890 and abandoned in 18973.............. |
| 2 | Aug.-Sept., 1888....... | No gas .......................... | ........................... |
| 3 | Sept.-Oct., 1888........ | Very strong flow of gas....... ..... | Quit suddenly, June, 1894.... ... |
| 4 | Oct.-Nov., 1888........ | Strong flow of gas.................. | Still yielding slightly............. |
| 5 | Dec.-Jan., 1889........ | Scarcely any gas.................... | Never used........... .......... |
| 6 | Feb.-Mar., 1889........ | Small flow of gas; rock close textured.... ........ ................ | Never used...................... |
| 7 | April, 1889............. | Scarcely any gas.................... | Never used...................... |
| 8 | June, 1889............. | A little gas; rock close textured.... | Never used...................... |
| 9 | Sept.-Oct., 1889........ | Strong flow of gas....... .......... | Has ceased to yield.............. |
| 10 | Sept.-Dec., 1890........ | Abandoned before reaching gas rock with loss of tools............ | ........................... |
| 11 | Oct.-Nov., 1891........ | Strong flow of gas.. ............... | Still producing.................. |
| 12 | November, 1891....... | Strong flow of gas.................. | Ceased producing suddenly...... |
| 12a | Nov.-April, 1892..... . | Abandoned at 480 feet with loss of tools.............................. | ........... ...................... |
| 13 | December, 1891........ | Strong flow of gas.................. | Producing....................... |
| 14 | December, 1891 ....... | Strong flow of gas.................. | Producing....................... |
| 15 | Jan.-April, 1892........ | Medium flow of gas................. | Producing....................... |
| 16 | April-May, 1892....... | Strong flow of gas.................. | Producing...... .................. |
| 17 | January, 1893.......... | Strong flow of gas.................. | Producing....................... |
| 18 | Mar.-April, 1893....... | No gas; rock close textured ........ | ........................... |
| 19 | May-June, 1893........ | A moderate flow of gas............. | Producing a little ................ |
| 20 | Dec.-Jan., 1894 ........ | Medium flow of gas................. | Producing....................... |
| 21 | April-May, 1894........ | No gas; rock close textured ........ | ........................... |
| 22 | June-Aug., 1894........ | ........................... | ........................... |

*Records of Borings*—Logs of the wells, showing the thickness of the strata passed through any kind of material, were kept of wells Nos. 1, 2, 3, 4, 5 and 8, which will be given hereafter. None are very reliable, though No. 8 seems most worthy of confidence. No records have been preserved of later wells. In the earlier wells, the gas was penetrated from four to seven feet; but in the later wells Nos. 12 to 20, the rock has been penetrated deeper, from ten to forty feet. Sometimes the flow has been increased by going deeper, other times not.

*Rock Pressure and Flow*—The confined pressure of the wells had never been accurately determined. No. 1 exceeded 200 pounds, but how much was never known. No. 3 reached 350 pounds on a steam gauge, the limit of the gauge. The later wells, Nos. 12, 13 and 14, had an initial pressure of from 180 to 200 pounds. This accords with experience in other fields, that the pressure lessens as the field is opened up.

But one measurement had been made of the open or flow pressure—on No 4, at an early date, by Mr. D. McNathy, of Louisville, Ky. This showed between four and five pounds through a two-inch pipe, which would represent a production of something over a million feet per day. This is, however, a maximum under the best conditions.

*Life of Wells*—No. 1 was greatly weakened by No. 3, which has probably produced a larger amount of gas than any other well. Nos. 3, 4 and 9, all within a few feet of each other, supplied the town for considerably more than two years; after which they still continued to yield, but had to be helped by additional wells. No. 3 has lasted about five and a half years; No. 4 is still yielding slightly, but shows signs of exhaustion. Seven years will represent the extreme life of a well in this area, under the best conditions. As the field is drained, the later wells cannot be expected to last as long or be nearly as productive as the early ones. During the winter of 1890-1, during the cold spells, the wells were allowed to flow freely, i. e., without any back pressure. The next winter showed them greatly weakened.

*Production and Cost*—The following data, for which, with many others, I am indebted to Mr. D. P. Barker, the obliging secretary of the Sparta Natural Gas and Oil Co., were furnished to the agent of the Census Bureau. They cover the year 1889:

| | |
|---|---|
| Total production of gas | 80,830,000 cubic feet. |
| Waste from leakage and other causes | 4,000,000 cubic feet. |
| Consumed for domestic fuel (400 fires) | 54,000,000 cubic feet. |
| Consumed in steam establishments (3) | 22,830,000 cubic feet. |
| Gas sold for | $3,842 30 |
| Tons of coal required for equivalent work | 3,340 |
| Value of coal displaced, at $1.50 per ton | $5,010 00 |

After the decline of the gas output no further drilling was done here, until after the discovery in Clark county. Since that time drilling has been carried on in the vicinity and five wells brought in, all being reported as small oil producers. Preliminary geological studies indicate that the field is on a small structural terrace. Additional drilling is now being done.

## MONTGOMERY COUNTY.

The following brief account of the field is condensed from the account published in 1906. It may be added that from recent drilling in this part of the State it now appears that the oil and gas came from beds representative of the Pottsville or a portion of the Chester.

"Oil was discovered many years ago while prospecting for coal, and for some years a small production was maintained by skimming the oil off the water in a mine sump. At Litchfield, Montgomery county, about 105 miles west of Casey and 40 miles south of Springfield, about 1886 a number of wells were drilled for oil and gas. Both were found at a depth of 640 to 670 feet, 'below the Lower Coal Measures, bordering on the Devonian.' About two and a half miles south of Litchfield a large gas well was struck in 1882, the pressure of which was between 400 and 450 pounds to the square inch. This well was spoiled by salt water in 1884. The well was drilled and cased at 580 feet, with no salt-water found in the gas sand, but after drilling down 200 feet further a heavy vein of salt water was struck. This could not be successfully plugged off, and finally drenched out the gas, which was reached at 640 feet.*

" 'The best gas was discovered at a depth of 666 feet. About seven miles of pipe were laid, ranging from three to eight inches in diameter, and the gas was supplied to about 500 stoves in Litchfield, being used chiefly for domestic purposes.'†

"In 1889 some of the wells began to yield oil, the yield being continued until 1903. In Mineral Resources of the United States for 1889, page 353, the following account of this oil production is given: 'The oil is a lubricating one, dark, almost black in color, and of 22° B. specific gravity. The cold test is remarkable, the oil remaining at 20° below zero, Fahrenheit. It is largely used by the factories in the neighborhood of Litchfield, and is sold to consumers at near-by points for lubricating purposes, bringing from 8 to 10 cents per gallon in bulk, according to quantity. In all there have been thirty wells bored in the neighborhood of Litchfield, chiefly for gas. The depth of these wells ranges from 640-670 feet. All save five were abandoned years ago. These five continue to produce the character of petroleum mentioned above. The average production of these wells is about four barrels per day. They are pumped by heads, and one man attends to them all. Natural gas from wells near by is used to some extent in furnishing fuel for pumping the wells. The supply of gas is about equal to twelve tons of coal a year, and twelve tons additional are used in pumping. The supply of natural gas is gradually diminishing.'

"Between 1889 and 1903, when the production ceased, the total yield of oil from Litchfield wells was 6576 barrels."‡

*Mineral Resources U. S., 1885, p. 167. †Mineral Resources, U. S., 1886, p. 512.
‡State Geol. Surv., Ill., Bull. 2, pp. 13-14.

## PIKE COUNTY.

From Mr. Savage's account of this field* the following brief account has been prepared because of the interest arising from this being the only known commercial occurrence of gas or oil in the State in the pre-Carboniferous rocks.

"Gas was first found in Pike county nearly twenty years ago, on the farm of Mr. Jacob Irick. The drilling was made for water, but a good pressure of gas was struck at a depth of 186 feet. The well was cased and the gas piped to the house to which it has since that time furnished an abundant supply for fuel and light. Soon after this a second well was attempted for water on the same farm. At a depth of 168 feet gas was again encountered. This well was near a barn and the hole was filled for fear of damage by fire. During the next fifteen years no effort was made to discover or utilize gas, although it was found in drilling a number of water wells over the area.

"In 1905 a well was put down on the farm of William Irick, in which a strong flow of gas was found. Mr. Irick recognized its value and at once piped the gas over his premises. Gradually the neighbors came to realize the advantages of using gas, and one after another put down wells in the hopes of obtaining supplies for their homes.

"Some weeks ago the gas rights on a tract of a few hundred acres of land in the northwest portion of Pittsfield township was leased for a nominal sum, but no effort has been made to exploit the field in a commercial way, or to determine the limits of the gas bearing strata. Down to the present time the development of the field has been wholly by owners of the land for local uses. Two drillers have been employed constantly for the past few months. Up to June 9, 1906, thirty wells have been put down in this field, all but six of which furnish a supply of gas.

"So far as at present exploited, the gas field of Pike county embraces an area about seven miles in length and four miles in width. It extends in a northwest-southeast direction across the central and northwestern portions of Pittsfield township and the northeast quarter of Derry, with one well further north in section 36 of township 4 south, range 5 west. A line drawn across the field from the center of the north side of section 1 of Derry township to the northeast corner of section 36 of Pittsfield will practically separate the area of productive wells from the non-productive portion of the field.

"The wells are all shallow, the gas being reached at a depth of 75 to 350 feet, depending largely upon the inequalities of the surface. There is evidence, too, that the beds dip strongly towards the east, along the east side of the area. An inclination of the strata towards the west is also shown along Dutch creek, beyond the western border of the field.

"The origin of natural gas and the conditions of its accumulation have been discussed in the preceding pages. In the Pike county field the gas occurs along an arch or anticline of strata, the eastern limb of which is closely determined by the line separating the productive from the dry wells. The porous stratum forming the reservoir is a bed of yellowish brown, more or less vesicular magnesian limestone which probably belongs to the Niagara. The thick bed of Kinderhook shales, that immediately overlies the Niagara limestone in this region, provides the impervious cover to the reservoir.

"The pressure of gas has not been measured in any of the wells over this field, but the supply furnished by an average well is many times more than is required for use in a single house. In the stronger wells when the drills penetrated the gas rock the outflow of gas was sufficiently strong to throw out the water and mud from the bottom, and in one case, a fragment of rock two inches in diameter was carried to the top of the hole. None of the wells have been shot.

"The gas has no unpleasant odor and it burns without smoke, giving a strong, bright flame.

*State Geol. Surv., Ill., Bull. 2, pp. 77-87.

"A slight showing of oil was reported from a few of the wells. Some of the samples of comminuted gas rock that were examined had a distinct odor of oil. A fragment of this rock at the home of Jerry Mink showed the discoloration as well as odor due to the presence of oil.

Since this was written the field has been extended by drilling until it now covers an area approximately ten miles long by four wide, with an outlying well about seven miles to the southwest near Summer Hill. The pressure is reported to be small but fairly uniform throughout the field. No oil has yet been found.

## Scattered Occurrences of Gas and Oil.

At a number of widely separated points small amounts of gas and oil have been observed outside the areas already discussed. Particularly since the development of the southeastern fields drilling has been wide-spread and while many dry holes have been put down some oil and gas has been reported. A small production has been found in Edgar county* and near Warrentown additional wells have recently been brought in. In Clay county, near Iola, some oil was reported at a depth of 252 feet.† Jasper county has so far yielded dry holes only as has also Wabash county despite favorable lithology and structural conditions.

In Saline, Williamson and adjacent counties it is not uncommon to get small amounts of gas at depths about the same as the workable coal. The pressure is light and the quantity seemingly small. In a few cases traces of oil have been observed. Near Tolono in Champaign county a hole put down in 1906 had a showing of oil in beds which seem to represent the Pottsville and Chester. The record, quoted below is of interest as showing the probable presence of these horizons so far north.

*State Geol. Surv. Ill., Bull. 2, p. 72. †Op. Cit., p. 73.
†Grout, F. F., State Geol. Surv., Ill., Bull. 2, pp. 73-74.

*Tolono Well Record—Fred Cross—No. 1.*

| No. | Description of Strata. | Thickness. Feet. | Depth. Feet. |
|---|---|---|---|
| 1 | Soil and gravel | 60 | 60 |
| 2 | Gravel, sand and water | 35 | 95 |
| 3 | Gravel, sand and water | 15 | 110 |
| 4 | Railroad sand | 28 | 138 |
| 5 | Sand and coal (wash coal) | 12 | 150 |
| 6 | Red fire clay | 18 | 168 |
| 7 | Gravel and clay | 52 | 220 |
| 8 | Light shale | 30 | 250 |
| 9 | Brown shale, little coal | 35 | 285 |
| 10 | Light shale } Oil | 11 | 296 |
| 11 | Oil sand } Oil | 9 | 305 |
| 12 | Gritty shale and sand | 85 | 390 |
| 13 | Lime shells } Oil sand 23 ft. | 47 | 437 |
| 14 | Brown shale and oil sand } Oil sand 23 ft. | 23 | 460 |
| 15 | Light shale | 5 | 465 |
| 16 | Brown shale | 22 | 487 |
| 17 | Dark shale | 6 | 493 |
| 18 | Light shale | 5 | 498 |
| 19 | Dark shale } Oil sand 25 ft. | 17 | 515 |
| 20 | White shale } Oil sand 25 ft. | 40 | 555 |
| 21 | Brown lime | 10 | 565 |
| 22 | Flinty lime | 8 | 573 |
| 23 | White lime | 10 | 583 |
| 24 | Sand "Big Water" | 17 | 600 |
| 25 | Sharp sand water | 120 | 720 |
| 26 | Sandy shale | 5 | 725 |
| 27 | Water sand | 37 | 762 |
| 28 | Sand, showing of oil | 6 | 768 |
| 29 | Sand | 57 | 825 |
| 30 | Brown lime | 14 | 839 |
| 31 | Sharp sand | 111 | 950 |
| 32 | Flint and particles of iron | 3 | 953 |
| 33 | Gravel | 9 | 962 |
| 34 | Sand | 18 | 980 |
| 35 | Lime | 10 | 990 |
| 36 | Sand | 23 | 1,013 |
| 37 | Lime | 14 | 1,027 |
| 38 | Water sand | 22 | 1,049 |
| 39 | Brown sand, showing oil | 5 | 1,054 |
| 40 | Sand and shale | 20 | 1,074 |
| 41 | Sand and oil | 5 | 1,079 |
| 42 | Sand and shale | 20 | 1,099 |
| 43 | Brown sand | 20 | 1,119 |
| 44 | Water lime stone | 70 | 1,189 |

Numbers 1 to 7 evidently represent the Pleistocene. Below it definite correlations can not now be made though the beds in which the oil occurs are suggestive of the Chester.

# ARTESIAN WELLS IN PEORIA AND VICINITY.

(By J. A. Udden.)

## Contents.

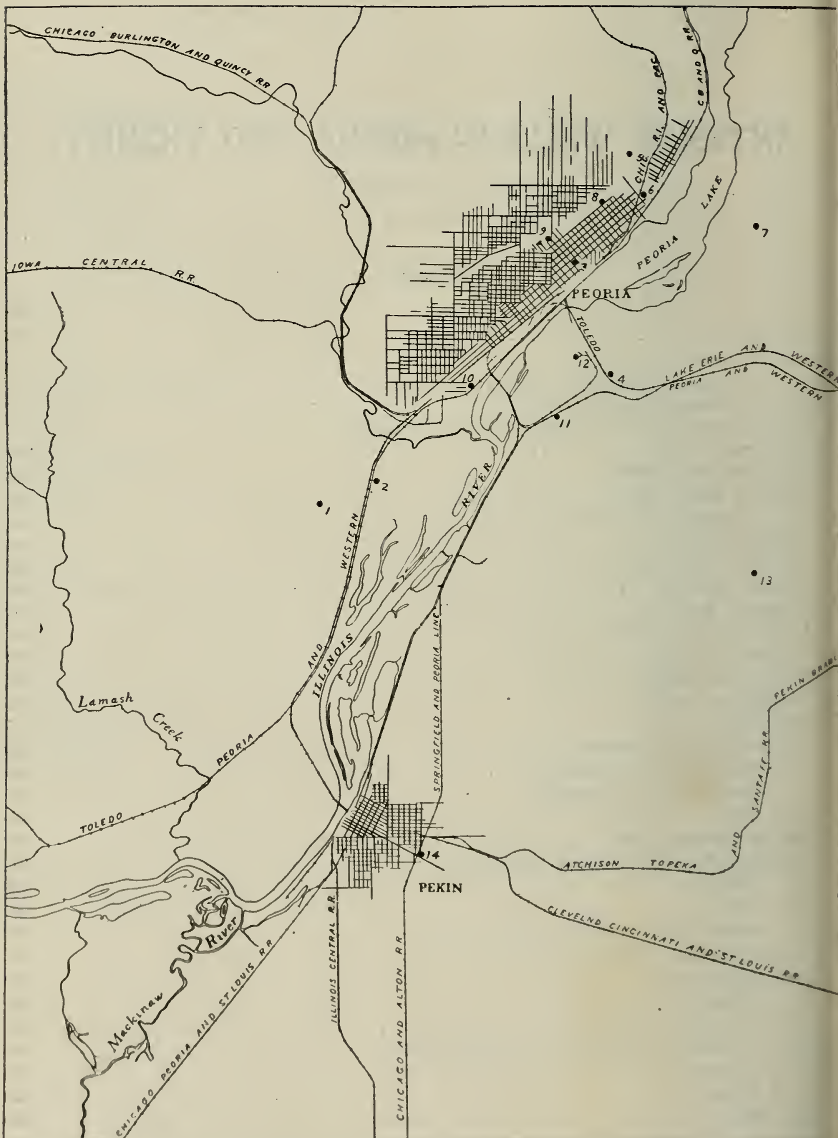



FIG. 30. Sketch map showing location of deep wells at Peoria.

## INTRODUCTION.

The first artesian well near Peoria was made on the east side of the Illinois river in 1860, when a flow of salt water was obtained at a depth of 317 feet. This boring was some years later carried to a depth of 734 feet, and a stronger flow of "sulphur water" was obtained. In 1875 two more wells were made on the west side of the river, the Spring Hill well and the Central Park well. In the following year Sidney Pulsifer sank another well at the foot of the bluff between Main and Hamilton streets. The next year Thomas McNeil tapped the "sulphur water" on the low bottom land at the stock yards, and a deeper well extending down in the Galena limestone was made on the O'Brian farm five miles southeast of Peoria. This last boring was on high ground and the water did not flow. In 1902 the Peoria Mineral Company finished a boring under the bluff on the east side of the river. This extended still deeper into the Ordovician limestones, and a strong flow of water was obtained. This boring was to some extent an enterprise looking to the discovery of petroleum. The following year the Illinois Asylum for the Incurable Insane at Bartonville drilled a well which is the deepest yet made in this vicinity. It extends into the St. Peter sandstone and reaches 1,864 feet below the surface. The lowest water rose within a short distance of the curb, but did not flow.

Various information has been collected on these and some other wells, bearing on the strata they pass through, on the quality and the heads of their flows, and on their mineral characteristics, etc. These data I shall here give for each well, and I shall then discuss them in a general way under suitable separate captions. The location of the wells is shown in figure 30, the numbers on the map corresponding to those in the text.

## DATA ON THE WELLS.

### 1. ILLINOIS ASYLUM FOR INCURABLE INSANE.

Location: One-tenth mile north of southeast corner of section 26, T. 8 N., R. 7 E.

Elevation of curb (aneroid estimate): 605 A. T.

Depth: 1,864 feet, contractor, J. P. Miller & Co.

Year: 1903.

Cost: $8,864.90.

Casing: 60 feet and 9 inches cased with 12 inch pipe; 421 feet 6 inches cased with 10⅝ inch pipe; 1,350 feet, 6 inch galvanized pipe.

Head: Lowest water came within 13 feet of surface. Heavy flow of water said to be from Trenton rock. St. Peter sandstone furnishes some water

from upper part, but little from lower part of the formation. Sulphur and salt water encountered at about 920 feet below the surface. Original hole from 885 feet to 1,350 feet, was 8 1-15 inches. This was afterwards reamed to 10½ inches.

Temperature: Lowest water, 78° Fahr.

LOG*

| | Thickness in feet. |
|---|---|
| *Drift*, 40 ft.† | |
| Loam (drift and coal measures?) | 40.0 |
| *Coal measures*, 382 ft. | |
| Coal | 3.6 |
| Shale | 17.3 |
| Rock | 3.6 |
| Shale | 90.9 |
| Coal | 4.6 |
| Shale | 262.0 |
| *Mississippian, not including the Kinderhook*, 228.6 ft. | |
| Lime rock‡ | 228.6 |
| *Devonian—Kinderhook*, 235 ft. | |
| Shale | 235.0 |
| *Niagaran*, 265 ft. | |
| Lime rock | 265.0 |
| *Cincinnatian*, 200 ft. | |
| Shale | 200.0 |
| *Galena—Trenton*, 315 ft. | |
| Trenton rock | 315.0 |
| *St. Peter*, 199 ft. | |
| St. Peter sandstone | 199.1 |
| Total | 1864.7 |

*Furnished by the superintendent of the asylum, Dr. George A. Zellar.

†Lines in italics give determinations by the author.

‡The meager descriptions and the lack of correspondence (especially in the case of this item) with the other records suggest that this log is perhaps in part a memory record. The greater thickness of this limestone, which certainly in part is the Burlington limestone, may otherwise be partly due to individual interpretation by the drillers. The logs of two of the other wells indicate that the "Kinderhook" is a more indurated rock than the shales below, and it may perhaps be included in the "lime rock" here measuring 228 feet.

## 2. Acme Harvester Company Well.

Location: Bartonville, south of Peoria.
Elevation: 460 feet A. T. (Estimate from topographic map.)
Depth: 366 feet.
Flowing water.

### *Log.**

| | Thickness. Feet. | Thickness. Inches. |
|---|---|---|
| *Drift*, 36 ft. | | |
| Drift | 30 | |
| Sand | 6 | |
| *Coal measures*. 267 feet, 8 inches. | | |
| Sand rock | 3 | |
| Argillaceous sand rock with hard bands | 20 | |
| Soap stone | 20 | |
| Iron band | | 5 |
| Dark shale | | 11 |
| Iron band | | 11 |
| Dark shale | 10 | |
| Slate | 3 | |
| Soapstone | 12 | |
| Coal | 2 | 8 |
| Fire clay | | 9 |
| Argillaceous soapstone | 14 | |
| Hard gray sandstone ("grit") | 10 | 4 |
| Coal | ...... | ...... |
| Fire clay | 1 | 8 |
| Hard gray sand rock | 8 | |
| Dirty soapstone | 12 | |
| Sand rock | 7 | |
| Almost a black shale | 11 | |
| Fire clay | | 4 |
| Dark shale with sulphur or spar bands | 15 | |
| Hard rock, sand rock with soft bands or wide partings | 8 | |
| Coal | ...... | ...... |
| Fire clay | 1 | 4 |
| Argillaceous rock, changing from black to white | 14 | |
| Sand rock with soft partings | 21 | |
| Coal | ...... | ...... |
| Argillaceous rock | 69 | |
| Clay | 1 | |
| *Mississippian, not including the Kinderhook*, 73 feet. | | |
| Limestone (easy drilling) | 47 | |
| Chert | 2 | |
| Limestone | 4 | |
| Chert | 5 | |
| Limestone | 2 | |
| Chert | 7 | |
| Porous yellowish rock with flowing water | 6 | |

*From Mr. C. W. Hicks, well driller.

This drilling was made for prospecting purposes, and the thickness of the coal seams was not obtainable, being informatian of confidential economic nature.

### 3. WELL AT SULPHUR WATER HOUSE BATHING COMPANY.

Location: No. 215 North Adams street, Peoria.
Elevation of curb: 485 feet A. T.
Depth: 861 feet.
Made in 1865.

*Log.**

| | Thickness in feet. |
|---|---|
| *Drift,* 87 feet. | |
| Soil | 2.0 |
| Yellow sand | 10.0 |
| Gravel with boulders | 75.0 |
| *Coal measures,* 240 feet. | |
| Blue clay | 66.0 |
| Dark shale | 25.0 |
| Blue shale | 48.0 |
| Limestone | 3.0 |
| Soft light colored limestone | 19.0 |
| Gray sandstone | 46.0 |
| Hard soapstone | 8.0 |
| Shale | 25.0 |
| *Mississippian, not including the Kinderhook,* 150 feet. | |
| Limestone | 25.0 |
| Blue porous limestone (salt water rose to within 4 feet of curb) | 13.0 |
| Flint limestone | 3.0 |
| Honey-combed limestone (salt water flowed) | 1.5 |
| Flint limestone | 7.5 |
| Porous limestone (flow increased) | 15.0 |
| Sandy limestone | 20.0 |
| Blue limestone | 65.0 |
| *Devonian-Kinderhook,* 297 feet. | |
| Blue shale | 55.0 |
| Blue limestone (flow now 250 gallons per minute) | 2.0 |
| Blue shale | 194.0 |
| Blue limestone (Devonian?) | 46.0 |
| *Niagaran,* 103 feet. | |
| White sandstone | 3.0 |
| Blue limestone, interstratified by streaks of shale in which the sulphur water increased at intervals | 100.0 |

Head of pressure of deepest water when first made, at least 545 feet A. T.
Head of water tapped at depth of 400 feet, at least 500 feet A. T.
Temperature of deepest water, 62° Fahr.

*Furnished by the proprietors.

4. Voris Well. (Also Called Bailey's Well.)

Location: East Peoria. On bottom land east of the T. P. W. R. R. and north of the river bluff, about one-tenth mile east of the center of the west line of section 32, T. 26 N., R. 4 W., Tazewell county.
Made in 1860. (This was the first flowing well made near Peoria.)
Elevation: 455 feet A. T. (Estimate from topographic map.)
Discharge 25,000 barrels per day.

*Log.**

| | Thickness in feet. |
|---|---|
| *Drift,* 28 feet. | |
| Alluvial soil of river bottom | 4 |
| Sand | 4 |
| Gravel (boulder drift) | 20 |
| *Coal measures,* 232 feet. | |
| Clay shale | 59 |
| Bituminous slate | 3 |
| Fire clay | 15 |
| Clay shale | 15 |
| Coal | 4 |
| Clay shale | 34 |
| Sandy and argillaceous shale (very hard) | 34 |
| Sandstone | 4 |
| Nodular argillaceous limestone | 6 |
| Compact fine grained sandstone | 5 |
| Hard, dark blue, sandy shale | 25 |
| Coal | 3 |
| Sandy and argillaceous shale | 25 |
| *Mississippian, not including the Kinderhook,* 134 feet. | |
| Bituminous shale with bands of limestone | 57 |
| "Cherty rock" | 44 |
| Hard siliceous rock, mainly chert (possibly chert and limestone intermixed) | 33 |
| Fine grained sandstone | 65 |
| At 774 feet, a gray porous limestone *(Niagaran).* | |

Notes from Peoria Transcript for Apr. 25, 1864, on this well:
(a) At 120 feet below surface, a four foot vein of coal.
(b) At 207 feet, salt water.
(c) At 235 feet, a three foot vein of coal.
(d) At 317 feet, salt water. This was the first water to overflow.
(e) At 734 feet, sulphur water. This rose more than 65 feet above the level of the bottom land.

*From Worthen's Geol. Surv., Ill., vol. IV, p. 180.

### 5. WELL IN GLEN OAK PARK, PEORIA.

Location: Glen Oak Park.
Elevation (aneroid): 534 feet A. T.
At depth of 440 feet water rose to within 6 feet of curb.
Sulphur water found at 824 feet and flowed with seven pound pressure, 200 gallons per minute.
Cost of well: $3,480.41.

*Log.**

| | Thickness in feet. |
|---|---|
| *Drift*, 150 feet. | |
| Gravel and clay | 150 |
| *Coal measures*, 250 feet. | |
| Coal measures (mostly shale) | 130 |
| Sand stone | 20 |
| Coal measures (mostly shale) | 80 |
| Shale with coal | 10 |
| Black shale, micaceous | 10 |
| *Mississippian, not including the Kinderhook*, 125 feet. | |
| Limestone (with chert and green shale) | 30 |
| Limestone (with some chert) | 50 |
| Limestone (crystalline, with crinoid stems) | 45 |
| *Devonian-Kinderhook*, 280 feet. | |
| Greenish shale, with sponge spicules (also chert) | 65 |
| Gray shale | 60 |
| Gray shale (pyritiferous and with *Sporangites huronense*) | 70 |
| Limestone | 20 |
| Limestone (with bryozoa) | 65 |
| *Niagaran*, 235 feet. | |
| Dolomitic limestone (some chert) | 100 |
| Dolomitic limestone (porous below) | 135 |

Borings examined by the author.
Head of water from 440 feet depth; within six feet of the curb.

*From samples kept in a glass tube in the office of the secretary of the City Park Commissioners.

### 6. Central Park Well.

Location: Corner Madison street and Abingdon avenue.
Depth: 925 feet.
Elevation: 476 feet A. T. (Estimate from topographic map.)
Daily flow: 600,000 gallons.
Made in 1875.

*Log.**

| | Thickness in feet. |
|---|---|
| *Drift*, 29 feet. | |
| Loam | 6 |
| Clay | 3 |
| Gravel | 12 |
| Quicksand | 8 |
| *Coal measures*, 341 feet. | |
| Coal | 4 |
| Shale ("Blue clay) | 26 |
| Rock ("coral rock") (sandstone?) | 30 |
| Soft soapstone | 6 |
| Rock ("coral rock") (sandstone?) | 45 |
| Soft gray soapstone | 19 |
| Blue shale | 17 |
| Soapstone | 194 |
| *Mississippian, not including the Kinderhook*, 94 feet. | |
| Slate | 5 |
| Blue limestone | 18 |
| Brown sandstone (with salt water) | 6 |
| Hard blue limestone | 65 |
| *Devonian-Kinderhook*, 287 feet. | |
| *Hard* (?) (record illegible, possibly Burlington limestone) | 45 |
| Blue slate | 14 |
| Soft shale | 200 |
| Slate | 6 |
| Limestone (?) (Devonian?) | 22 |
| *Niagaran*, 164 feet. | |
| Blue limestone 52 feet | 52 |
| Brown sandstone (with mineral water) | 76 |
| Porous limestone | 36 |

*From an old record in possession of owners.

### 7. PEORIA MINERAL COMPANY WELL.

Location: Hart Lee farm, under the bluff in the northwest quarter of section 22, T. 26 N., R. 4 W.
Elevation of curb: 475 feet A. T. (Estimate from topographic map.)

*Log.**

| | Thickness in feet. |
|---|---|
| *Drift,* 101 feet. | |
| Loam | 4 |
| Sand and gravel | 97 |
| *Coal measures,* 289 feet. | |
| Blue clay | 40 |
| Black limestone | 6 |
| Coal and slate | 4 |
| Blue clay (shale) | 50 |
| Coal and slate | 20 |
| Soapstone | 55 |
| Slate | 104 |
| Gray sandstone | 10 |
| *Mississippian, not including the Kinderhook,* 96 feet. | |
| Slate (Coal measures?) | 5 |
| White limestone | 10 |
| Porous limestone | 81 |
| *Devonian-Kinderhook,* 271 feet. | |
| Slate | 123 |
| Slate rock | 2 |
| Slate | 88 |
| Gray limestone with zinc | 5 |
| White shale with zinc | 10 |
| White porous limestone | 43 |
| *Niagaran,* 263 feet. | |
| Flint limestone | 43 |
| White limestone | 21 |
| Porous limestone | 39 |
| White porous limestone and quartz | 80 |
| Gray limestone | 80 |
| *Cincinnatian,* 198 feet. | |
| Slate | 85 |
| Black limestone | 6 |
| Slate | 59 |
| Black limestone | 10 |
| Slate | 38 |
| *Trenton and Galena,* 199 feet. | |
| Limestone | 20 |
| Sandstone | 23 |
| Coarse sandstone | 26 |
| Trenton rock | 130 |

Notes: Salt water at least 325 feet below the curb. The well diminished the flow in the Glen Oak Park well, and was hence shut off. The water in this well had a pulsating flow.

Sulphur water comes from 700 feet below surface with a reported pressure of 120 pounds. This is probably a mistake. If this water *rises 120 feet* it it would stand at about the same level as the Pekin and Asylum wells. Lowest water came from 1400 feet below the surface.

*From record furnished by the company.

### 8. SPRING HILL WELL.

Location: At foot of bluff near crossing of Spring street and Glen Oak avenue.
Made in the early part of 1875. (First well made west of the river.)
Depth: 875 feet.
Elevation of curb: 550 feet A. T. (Estimate from map.)
Discharge: 150 gallons per minute.

### 9. PULSIFER WELL.

Foot of bluff between Main and Hamilton streets.
Made in 1876.
Depth: 912 feet.
Elevation of curb: 540 feet A. T. (Estimate from map.)
Discharge: 105 gallons per minute.

### 10. THOMAS MCNEIL WELL. (In Stock Yards.)

Location: South part of city, on low bottom land.
Elevation: 460 feet A. T.
Depth: 860 feet.
Throws water at least 60 feet above ground.

### 11. CARTER'S WELL.

Location: At foot of bluff in Carter's brickyard in East Peoria, Tazewell county.
Elevation of curb; 465 feet A. T. (Map estimate).
Pressure: Water now rises at least 20 feet above curb.
Originally it rose 65 feet above the curb.
Depth: About 370 feet.
Main water, which is salty, comes from the lower ten feet.
Four inch coal at 302 feet below the surface.
"Section much like that of the Acme Harvester well."

### 12. COLEAN FACTORY WELL.

Location: On bottom land, near northeast corner of section 31, T. 26 N., R. 4 W., Tazewell county.
Elevation of curb: 453 feet A. T.
Depth: 320 feet.

*Log.*

The drift is 90 feet deep. The shales of the coal measures were noted as having more "spar" and calcareous concretions than at other points, and the coal was less pure, as if somewhat broken up. At a depth of about 310 feet there was considerable white chert (Burlington limestone). Coal was discovered at 190 feet below surface.

### 13. O'BRIAN WELL.

Location: One-third mile west of the northeast corner of section 14, T. 25 N., R. 4 W., Tazewell county.
Elevation of curb: 738 feet A. T. (Map estimate.)
Depth: 1,442 feet.
Made in the summer of 1876.
Water did not flow.
Salt water obtained at a depth of from 600 to 700 feet.
Sulphur water came from a depth of 1,050 feet. Water also obtained from a porus rock, called "Trenton" rock by the drillers, in the lowest fifty feet of the boring. This rock was porous. Flint was reported by the drillers at a depth of 1,200 feet from the surface.

### 14. PEKIN CITY WELL.

Location: One-quarter mile south from the crossing of the Chicago and Alton railroad and the Atchison, Topeka and Santa Fe railroad in the east part of Pekin, Tazewell county.

Elevation of curb: 630 feet A. T. (Map estimate.)

Depth: 990 feet.

Flow: 400,000 gallons per day.

Salt water flowed from a stratum at a depth of 425 feet.

Principal flow of sulphur water from below 850 feet.

Very porous rock at 950 below surface.

Water rises 60 feet above the ground.

*Log.*

| | Thickness in feet. |
|---|---|
| *Drift,* 120 feet. | |
| Sand and gravel | 120 |
| *Coal measures,* 180 feet. | |
| Soapstone and slate | 180 |
| Seam of coal | ? |
| *Mississippian, Devonian, and Silurian,* 690 feet. | |
| White limestone rocks* | 500 |
| Porous stone* | 190 |

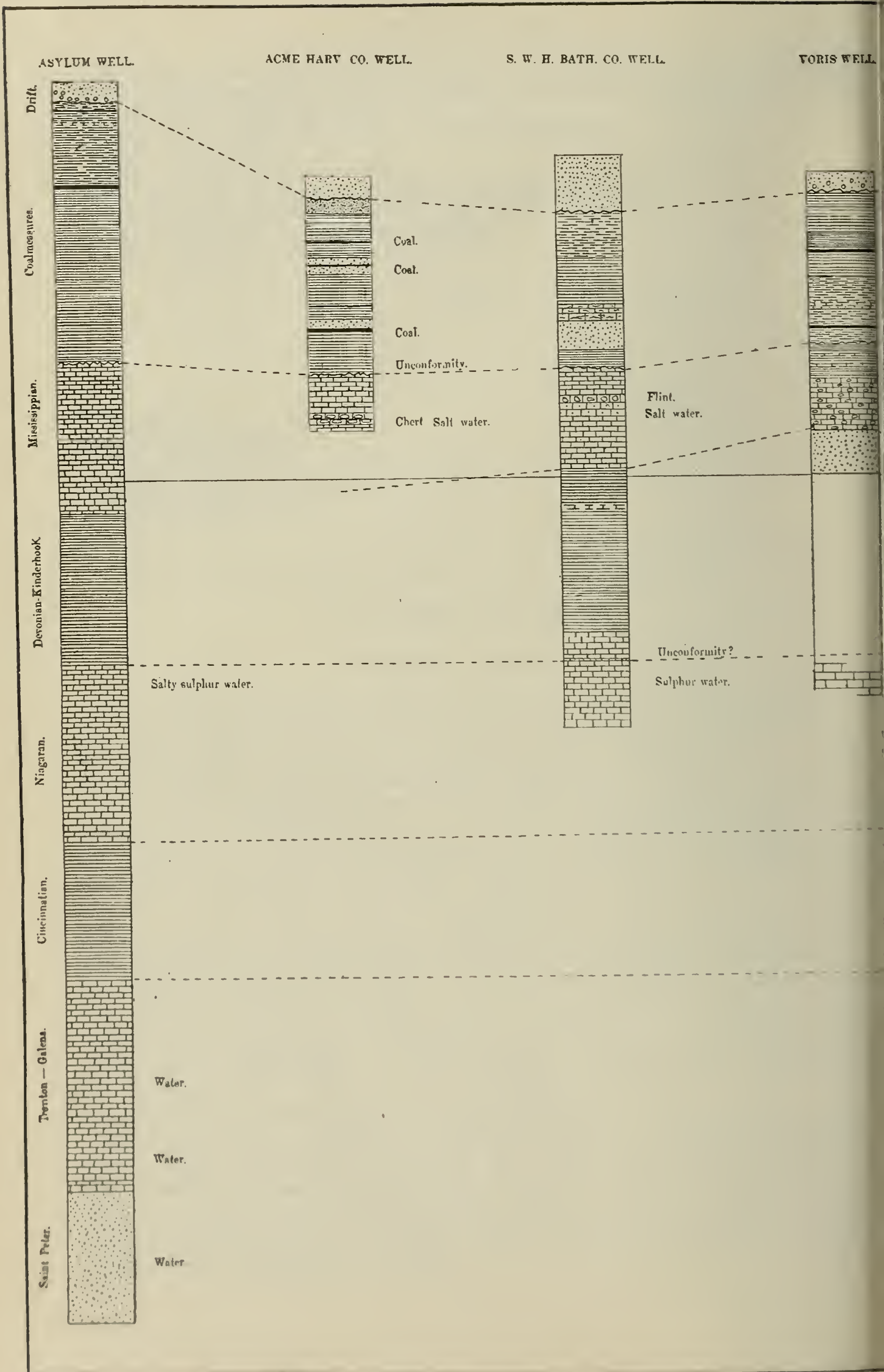
*This is a memory record, and these two items are evidently amiss.

## THE UNDERLYING ROCKS.

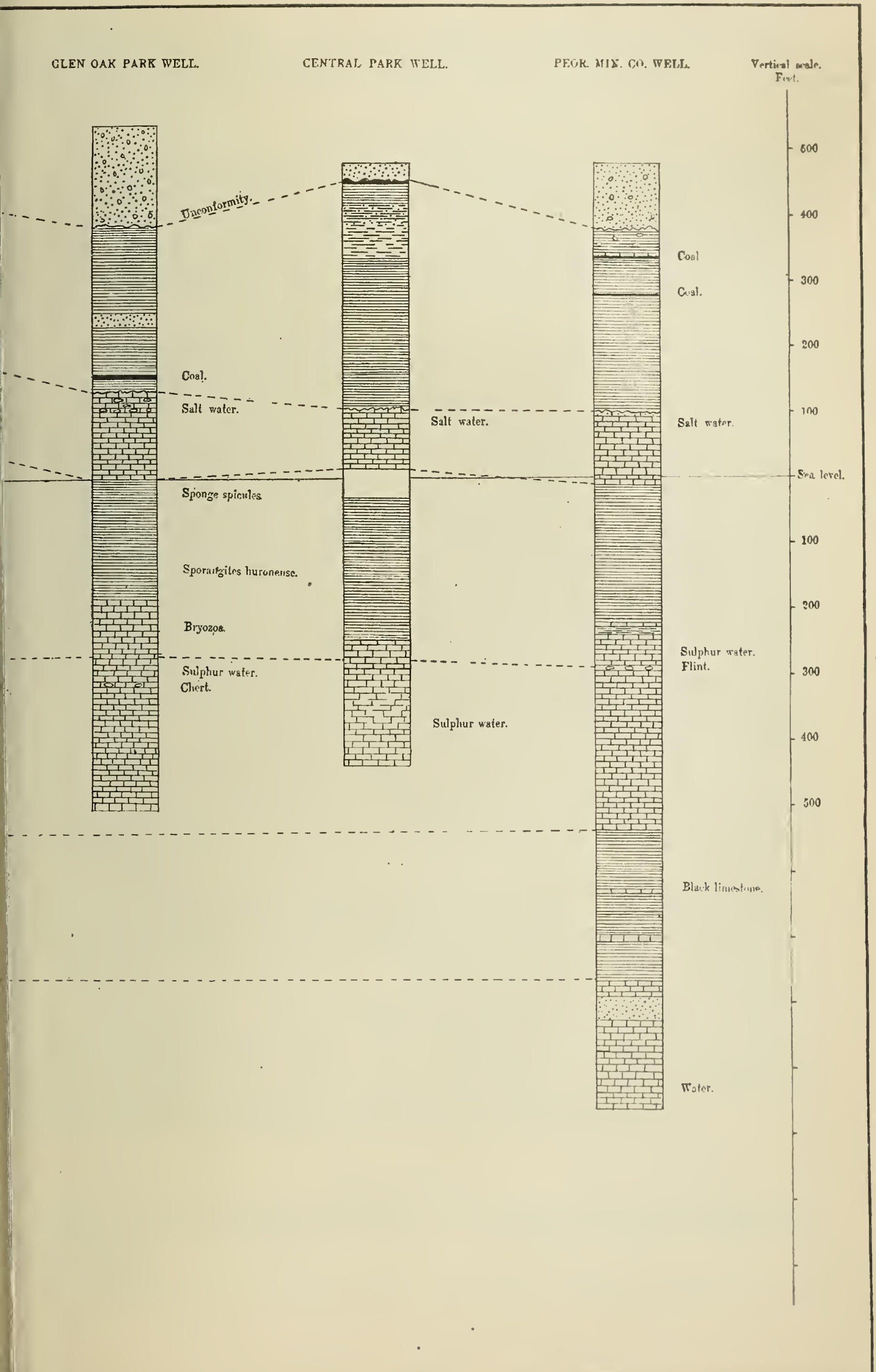
### GENERAL STATEMENT.

From the above notes and from what is known of the geology of the north part of the State, the nature of the strata underlying Peoria is readily made out down to the bottom of the deepest well. A study of the logs that have been accurately kept shows that there is a close correspondence among the several records, although made by different drillers and at different times. In the case of the Glen Oak park well the author was given an opportunity to examine the drillings and succeeded in finding miscroscopic fossils, by which the lower part of the shales intervening between the Burlington limestone can now with greater assurance than before be referred to the Upper Devonian series. The evidence on which such reference has previously been made for the wells on the Illinois river was that of stratigraphic position only. On similar evidence the upper part of this bed of shale has been regarded as the equivalent of the clay underlying the Burlington limestone on the Mississippi. This conclusion has also been verified by the finding in the Glen Oak well drillings of sponge spicules, which are known from these clays on the Mississippi.

Excepting these argillaceous sediments and the Burlington limestone above them, the entire section for the Peoria wells can be traced in the records of other borings to their respective outcrops farther north. This is owing to the fact that the Devonian and the Lower Carboniferous were cut away by erosion before the coal measures were laid down over the northern territory.


ASYLUM WELL.
ACME HARV CO. WELL.
S. W. H. BATH. CO. WELL.
VORIS WELL.
Drift.
Coalmeasures.
Mississippian.
Devonian-Kinderhook.
Niagaran.
Cincinnatian.
Trenton — Galena.
Saint Peter.
Coal.
Coal.
Coal.
Unconformity.
Chert Salt water.
Flint.
Salt water.
Unconformity?
Sulphur water.
Salty sulphur water.
Water.
Water.
Water

DEEP W


GLEN OAK PARK WELL.
CENTRAL PARK WELL.
PEOR. MIX. CO. WELL.
Vertical scale.
Feet.
600
400
300
200
100
Sea level.
100
200
300
400
500
Unconformity.
Coal.
Salt water.
Sponge spicules.
Sporangites huronense.
Bryozoa.
Sulphur water.
Chert.
Salt water.
Sulphur water.
Coal
Coal.
Salt water.
Sulphur water.
Flint.
Black limestone.
Water.

' PEORIA.

In the account which follows the different formations are given in the order of their stratigraphic succession, beginning with the oldest rocks. The correlation of the records is shown in plate 22.

## THE ORDOVICIAN.

*a. St. Peters Sandstone*—The lowest formation explored by drilling in the vicinity of Peoria is the St. Peters sandstone. This was penetrated to a depth of 199 feet by the well made at the Asylum for the Incurable Insane at Bartonville. The drillers report the rock merely as St. Peters sandstone. This identification is doubtless correct, for it underlies the Trenton limestone, which has been explored by two other wells.

*b. Trenton-Galena Formation*—The log of the asylum well reports 315 feet of "Trenton rock" immediately above the St. Peters sandstone. The log of the Peoria Mineral Company gives a more descriptive account of this part of the section, and shows some unusual changes in the nature of the strata. Under the uppermost twenty feet, which is limestone, there is twenty-three feet of sandstone, and below this twenty-six feet of the "coarse sandstone." The lowest hundred and thirty feet are reported as "Trenton limestone." The typical Trenton probably makes the lowermost 130 feet. This boring, no doubt, penetrated the Galena formation. This is free from sandy strata in the north part of the State, and the sand and the coarse sand reported in this place is probably a cavern filling or the dolomite of the Galena phase. The cavern filling hypothesis is all the more likely, as other evidence indicates an unconformity between the Galena limestone and the overlying Cincinnatian formation in the region west of the Cincinnati anticline.* The combined thickness of the strata which it seems correct to refer to the Galena-Trenton formation, in this log measures 199 feet. The O'Brian well, which is on the east side of the river, is reported to have entered this rock and to have gone into it some half a hundred feet, and it is said to have been porous and water bearing in this well also.

*c. The Cincinnatian Formation*—Three wells have penetrated this formation. The record of the asylum well reads: "Shale, 200 feet." The Peoria Mineral Company recorded five different strata, which must be referred to this formation. There were three "slates," separated from each other by two strata of "black limestone," one six and the other ten feet thick. It is probable that the black appearance of these limestones may have been due to the presence of pyrites of iron, which often impregnates these strata. The total thickness of the five members of the formation, as reported from his boring, is 198 feet, only two feet less than the thickness reported from the asylum well.

## THE SILURIAN.

This formation furnishes most of the artesian water now flowing in this region. It has been entered by no less than fourteen wells, but

*The Geological Map of Illinois, Stuart Weller, Bull. 1, Illinois Geol. Surv., p. 16.

ony two of these are known to have passed through it. In the log of the Peoria Mineral Company's well the strata which I refer to this division measures 263 feet. The equivalent "lime rock" reported from the asylum well measures 265 feet. The several samples from the Glen Oak park well show that the lowest 235 feet in this well was drilled through a highly dolomitic limestone, no doubt of this age. Drusy quartz lined the surface of one fragment from the upper part of the formation. In the drillings from the upper 100 feet of the formation several minute rounded and flat grains of quartz were observed, which contained a tangle of miscroscopic straight needles of some transparent mineral. The lower part of this limestone was seen to be quite coarse grained in places, and the drillings contained lumps of green clay such as is common in fissures produced by solution. Most of the records of the other wells describe the formation as "limestone" and "lime rock." Parts of it are called "porous limestone;" and "white chert," "quartz" and "flint" are reported as present in three wells, in one case in the upper part of the formation and in two instances near the base. In one well seventy-six feet of brown sandstone is reported as the source of the water near the middle of the formation. This is probably a mistake. If it is not, the sand is probbly a cavern filling. Three feet of white sandstone and of pockets of clay lower down are reported from near the top of the Niagaran, in the Sulphur Water House Bathing Company's well. This sandstone may mark the division between this formation and the overlying Devonian. The forty-six feet of limestone which overlies is decribed as blue limestone, and this is usually not the appearance of the upper part of the Niagaran. The water which flows from the Niagaran has a strong odor of hydrogen sulphide.

## DEVONIAN-KINDERHOOK.

Five records show the presence above the Silurian of some beds which average 283 feet in thickness and which are overlain by a limestone that is identifiable as the Burlington limestone. The main and upper part of these beds is a shale, which has been variously reported by the drillers as "slate," "slate rock," "white shale," "blue slate," "soft shale." The lower part, some eighty feet thick, is a limestone, sometimes described as "blue limestone," as "white limestone" or merely as "limestone." This limestone is, without doubt, of Devonian age. In the Glen Oak Park well it measures eighty-five feet and is quite a pure carbonate of lime, which effervesces briskly with acid. The drillings contain frequent particles of crystalline calcite. Several minute fragments of bryozoa and some other organic materials were noted. In the Peoria Mineral Company's log mention is made of the occurrence of "zinc" (blende?) near the top of this limestone.

All of these features are characteristic of the Wapsipinnicon and the Cedar Valley limestones, which overlie the Niagara formation on the Mississippi river, in Rock Island county.

The overlying shale measures some 200 feet. The upper part of this shale has a greenish aspect. A microscopic examination of the samples from the Glen Oak park well shows the frequent presence of siliceous sponge spicules and some other organic fragments Granules of pyrite were common. The middle part of the shale is gray and slightly calcareous and contains a few minute flakes of mica, small clusters of cubic crystals of pyrites and spores of some lycopods. The lowermost seventy feet of the shale is of an olive color and likewise has occasional minute flakes of mica and aggregations of minute crystals of pyrites. In this latter part of the shale *Sporangites huronense* is quite abundant.

The Central park record indicates some alterations in hardness in the upper part of this clayey member, and in the Sulphur Water House Bathing Company well a two foot blue limestone was penetrated, which appears to have yielded some water. An indurated stratum at about the same level is reported in the Peoria Mineral Company's log as "slate rock."

It is believed that the lowermost part of this shale is identical with the Sweetland creek beds overlying the Cedar Valley limestone, in Muscatine county, in Iowa, and in Rock Island county, in this State. *Sporangites huronense* is abundant in these localities. This shale is classified as a western formation of the Chemung period. The upper part of the shales in the Peoria wells is probably equivalent to what is generally known as the Kinderhook shale, underlying the Burlington limestone farther to the south, for the Kinderhook shale is known to contain fossil sponges at the latter place, and it has the same stratigraphic position. As the Kinderhook shales are classified with the Lower Carboniferous, these shales may hence include the latest sediments of the Devonian age and the earliest deposits of the Carboniferous age.

### MISSISSIPPIAN (BURLINGTON LIMESTONE, ETC.)

Between the coal measures and the Kinderhook-Devonian shales just described all of the logs record a limestone, which, no doubt, is the equivalent of the Burlington limestone on the Mississippi river. All of the flowing wells have entered this formation and ten have passed through it. Six logs gave more or less complete records and four give partial records of the materials which this formation contains. The samples of drillings from the Glen Oak park well consist of a light colored calcareous limestone mixed with much white chert. The uppermost thirty feet, also, in this well contained a considerable amount of green shale. The lowest forty feet had less chert and no shale, but considerable calcite spar and some fragments of crinoid stems. Chert was seen by the author from the bottom of the Carter well and from the well of the Acme harvester works, and it is reported from seven of the logs in his horizon. It is a white or light gray chert and resembles the chert in the Burlington limestone in appearance. The upper part of the limestone has yielded salt water in all of the wells, and the water bearing rock is close to the cherty strata. Above the main limestone alternations of the shale and bands of limestone are

mentioned in the log of the Voris well. Some "slate" is reported from above the limestone in the logs of the Central park well and in the Peoria Mineral Company's well. It seems likely that these apparently variable beds may represent some later division of the Lower Carboniferous series, but in the absence of fossils it is not possible to definitely locate the boundary between this series and the coal measures. In the case of variable beds, considerable latitude is taken by drillers in their reports as to the noting of details.

It is evident that the main limestone at this depth is about a hundred feet in thickness. Not taking into account the log of the asylum well, the thickness of the strata which appear to be referable to the Burlington limestone and overlying Lower Carboniferous, varies from 94 feet in the Central Park well to 150 feet in the well of the Sulphur Water House Bathing Company. The average is 120 feet. There is hardly any doubt that this variation in the observed thickness of these beds is at least partly due to an unconformity between the Mississippian series and the coal measures. This unconformity is general on the Mississippi, and it is indicated for this region by the disappearance of the Mississippian limestone from the well records to the north. This rock is absent in the wells at Hennepin.

## PENNSYLVANIAN OR COAL MEASURES.

The thickness of the coal measures varies from 232 feet, in the Voris well, to 381 feet, in the asylum well. The variation, in part, is probably due to the uneven bottom of the Mississippian sediments on which the formation rests; to the inequalities of its surface produced by erosion.

The asylum well, which is located on the upland, goes through more than a hundred feet of coal measure strata, which overlie the beds penetrated in the other wells. The average depth of the coal measures in the borings made on the river bottom is 270 feet. Most of this consists of shales, in which are at least four seams of coal. These coal seams nowhere appear in outcrops in this region. The absence of any mention of the existence of these coals in some of the logs is clearly due to difference in the degree of detail of description. The detailed accounts show that the shales vary in color and texture. There are dark and bituminous strata and seams of fire clay, layers of limestone and seams with nodules of calcareous material. Some of the sediments are near the limit between shale and fine sandstone, such as "argillaceous sandrock" and "sandy shale." About two-thirds of all is shale and perhaps one-fifth is sandstone. The rest is coal, fire clay, limestone and sandy shale.

## DRIFT.

The average thickness of the drift shown in these records is eighty feet. The least is twenty-eight feet and occurs in the Voris well: and the most is 150 feet, in Glen Oak park. In the wells on the lowlands most of the drift consists of sand, gravel and river silt, but there is also

occasionally some boulder clay. In the asylum well the depth of the drift is uncertain. The coal measures appear in a ravine close to this well, at about twenty feet below the level of the curb.

*General Section of the Peoria Wells.*

| | Thickness in feet. |
|---|---|
| 8. Drift; sand, gravel and silt | 80 |
| Unconformity. | |
| 7. Coal measures; shale, sandstone, coal, etc | 270 |
| Unconformity. | |
| 6. Mississippian (not including the Kinderhook); limestone with layers of chert and some shale | 120 |
| 5. Devonian-Kinderhook; limestone below and shale above | 283 |
| Unconformity. | |
| 4. Niagaran; dolomitic limestone with some chert | 264 |
| 3. Cincinnatian; mainly shale | 200 |
| 2. Trenton-Galena; dolomitic limestone | 315 |
| 1. St. Peters sandstone | 199 |

## THE WATER BEARING HORIZONS.

Three water bearing horizons have been tapped by the Peoria wells: the Burlington limestone, the Niagaran limestone and the Ordovician, including the Galena-Trenton formations and the St. Peters sandstone.

*The Ordovician*—This is the deepest of all the formations penetrated. In the asylum well the bulk of this water is said to have come from the upper part of the Galena-Trenton limestone, but the supply is said to have increased when the boring entered the St. Peters sandstone. This formation is the principal water bearing rock in the upper Mississippi valley. As the sandstone is not separated from the overlying limestone by any impervious stratum, it is very likely that the waters in the two formations are in hydrostatic communication through joints and fissures in the overlying limestone. In Davenport and Rock Island, lying only ninety miles to the northwest from Peoria, the same condition is indicated by the absence of any notable difference in the head of the waters coming from these two formations. In the Peoria Mineral Company's well this water was obtained in the Galena limestone at a depth of 1,400 feet. Whether the water reported from the same depth (but from a higher level referred to the sea) in the O'Brian well was from the Ordovician, can not be definitely settled in the absence of a log.

Compared with the other artesian waters of this locality, the Ordovician contains the smallest amount of solids in solution; only about 1,600 parts in a million. Most of this consists of sulphates of sodium and calcium, which are present in about twice the quantity of the chlorine compounds of the same elements.

The intake area of the Ordovician is in the north part of the State and in the south part of Wisconsin.

*The Niagaran*—This water has been tapped at depths ranging from seven hundred to a thousand feet. In most cases it has come from a horizon at nearly a hundred feet below the upper surface of the

Niagaran limestone, where this is reported as of a porous texture, and where cherty seams are reported in some instances. It may be surmised that the greater mobility of the rock water at this level first caused the concentration of the silica in the form of chert and later increased the porosity of the rock. In the Peoria Mineral Company's well this water was drawn from the uppermost surface of the Niagaran, or perhaps from the base of the overlying Devonian strata, owing probably to some upward extensions of the porous rock. It is well known that the upper part of the Niagaran is characterized by pronounced local variations in texture and bedding. In all the outcrops nearest to Peoria it exhibits oblique bedding.

The water of the Niagaran formation is the principal flow in Peoria. It now runs in nine wells. It contains about twice the amount of mineral solids in solution present in the Ordovician water. Three analyses from as many of the Peoria wells show a notable constancy in the mineral character of this water. Chlorine varies from 1,395 to 1,562 parts in a million and sedium oxide only from 1,452 to 1,486 parts in a million. Sulphates ($SO_3$) are present in less than half the quantity in which they occur in the Ordovician, ranging from 199 to 246 parts in a million. Common salt is the chief mineral in solution, making more than two-thirds of all the solids. The presence of hydrogen sulphide is a no less constant characteristic, readily detected by its odor, though not appearing in the analyses.

The Niagara outcrops over a tract of several thousand square miles around Lake Michigan, in this State, and in Indiana, and over another large area on either side of the Mississippi river, in this State and in Iowa. These tracts are the intake areas of the Niagaran water, especially the region on the Mississippi.

*The Burlington Limestone*—The uppermost horizon which has yielded flowing water is the main limestone of the Mississippian. This formation is separated from the Niagaran by the Devonian-Kinderhook shales, which effectually separate its waters from those of the lower horizons. Northward and eastward this limestone thins out and terminates under the impervious argillaceous sediments of the coal measures, but to the west it outcrops in a belt along the Mississippi river. This belt is the intake area of this water horizon. Of course, it is possible that some water may also enter from the basal sands of the coal measures into the buried unconformable north margin of the Burlington.

The Burlington water has been noted in all the Peoria wells, except at the Illinois Asylum for the Incurable Insane. In six wells it comes from ledges which are reported to contain seams of chert, which mostly occur in the upper part of the rock. In one instance the water is noted as coming from the middle part of the limestone and in one case from the lowermost ledges. In the region of the outcrop of the formation on the Mississippi river these same strata frequently give issue to large springs.

The water of the Burlington limestone carriers more minerals than either of the other two waters. Analyses have been made of samples from the wells of the Acme Harvester Works, of Carter's brickyard

and of the Peoria Mineral Company, and these show a close correspondence. They vary from 7,191.8 to 8,859.8 of total mineral matter in parts per millin and average 8,284.9. More than nine-tenths of this is common salt. Sulphates ($SO_3$) average 10.2 parts per million, which is only one-twentieth the amount of sulphates in the Niagaran water and less than one-fiftieth the amount in the Ordovician.

*Comparative Table of Analyses of the Artesian Waters in tne Peoria Wells.* (*In parts per Million.*)

| Minerals in Solution. | | Ordovician. | | Niagaran. | | | Burlington. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | a.—Peoria Mineral Co. well, depth 1,450 ft... | b.—Asylum well, depth 1,864 ft .......... | c —Unknown well, depth 980 ft ........ | d.—Peoria Mineral Co. well, depth 1,000 ft... | e.—Central park well, depth 875 ft ........ | f.—Acme Harvester well, depth 366 ft.... | g.—Peoria Mineral Co. well, depth 500 ft.... | h.—Carter's well, depth 370 ft ....... |
| Potassium, | $K_2O$ | 25.0 | 17.6 | 30.1 | 36.8 | ........ | ........ | 38.4 | ....... |
| Sodium, | $Na_2O$ | 544.2 | 592.8 | 1,463.1 | 1,452.4 | 1,486.6 | 4,071.8 | 3,358.2 | 4,036.0 |
| Ammonium, | $NH_4$ | 1.5 | ........ | 1.9 | ........ | 2.1 | 3.2 | ........ | 3.1 |
| Magnesium, | MgO | 32.6 | 44.8 | 34,4 | 48.6 | 42.3 | 59.4 | 39.4 | 65.8 |
| Calcium, | CaO | 71.8 | 96.4 | 59.6 | 79.8 | 68.9 | 78.8 | 70.8 | 74.5 |
| Iron, | FeO | .4 | .2 | 3.6 | .8 | 2.6 | 3.0 | 3.4 | 2.0 |
| Aluminum, | $Al_2O_3$ | 2.4 | | | 2.2 | 4.0 | | 5.4 | 20.2 |
| Nitrate, | $N_2O_3$ | ....... | 1.7 | ....... | ....... | ....... | ....... | ....... | ....... |
| | $N_2O_5$ | .4 | .7 | .6 | 0.6 | 0.6 | 0.3 | 0.7 | 1.3 |
| Chloride, | Cl | 212.3 | 297.0 | 1,562.5 | 1,395.0 | 1,425.0 | 4,637.5 | 3,637.0 | 4,579.1 |
| Sulphate, | $SO_3$ | 486.8 | 537.2 | 198.8 | 246.0 | 226.1 | 1.0 | 14.4 | 15.2 |
| Silica, | $SiO_2$ | 26.6 | 10.4 | 16.8 | 11.4 | 11.2 | 7.8 | 24.4 | 6.0 |
| Totals .................... .... | | 1,404.1 | 1,597.9 | 3,367.7 | 3,273.6 | 3,269.4 | 8,859,8 | 7,191.7 | 8,803.2 |
| Averages ..................... | | 1,501.0 | | | 3,303.6 | | | 8,284.9 | |

*a.* Analysis made by University of Ill. Laboratory number: 10,380.
*b.* Analysis made by University of Ill. (Edgar and Carr) Laboratory number: 12,164.
*d.* Analysis made by University of Ill., Feb. 20, 1902, Laboratory number: 10,280. Analyst Robt. W. Stark.
*c.* Analysis made by University of Ill., Sept 8, 1904, Laboratory number: 12,415.
*e.* Analysis made by University of Ill. (J. M. Lindgren). Laboratory number; 15,250, Jan. 25, 1907. Recalculated for comparison by Dr. J. P. Magnuson. Potassium calculated as sodium.
*f.* Analysis made by University of Ill., June 18, 1902. Laboratory number: 10,464. Potassium calculated as sodium.
*g.* Analysis made by University of Ill., Feb. 20, 1902. Laboratory number :10,230. Analyst, Robt. W. Stark.
*h.* Analysis made by University of Ill. (J. M. Lindgren) Jan. 24, 1907. Laboratory number: 15,241. Potassium calculated as sodium. Recalculated for comparison by Dr. J. P. Magnuson.

## QUANTITY OF FLOWS.

Data on the original quantity of water supplied by some of these wells is as below:

*From the Niagaran.*

| | Gallons per minute |
|---|---|
| Voris well | 546 |
| Central Park well | 416 |
| Pekin well | 277 |
| Sulphur Water House Bathing Company's well | 250 |
| Glen Oak Park well | 200 |
| Spring Hill well | 150 |
| Pulsifer well | 105 |
| Peoria Mineral Company well | Shut off. |
| Asylum well | Shut off. |
| Stock yards well (estimate) | 400 |
| Total | 2,344 |

*From the Burlington.*

| | Gallons per minute |
|---|---|
| Acme Harvester Company well (estimate) | 100 |
| Carter Brickyard well (estimate) | 100 |
| Colean Factory well (estimate) | 100 |
| Total | 300 |

The Ordovician water is not now used.

The difference in the quantity of water yielded by the wells tapping the Niagara limestone is due to some extent to difference in the size of the borings, but it is evidently mostly due to differences in elevation, causing variation in pressure. The largest flows are from the wells with lowest curbs. This is clearly shown in the following table:

| | Elevation of curb, in feet A. T. | Flow in gallons per minute. |
|---|---|---|
| Spring Hill well | 550 | 150 |
| Pulsifer well | 540 | 105 |
| Pekin well | 530 | 277 |
| Sulphur Water House Bathing Co. well | 485 | 250 |
| Central Park well | 476 | 416 |
| Voris well | 455 | 546 |

## HEAD OF FLOWS.

Specific data on the original artesian heads are in most cases not to be obtained. The water of the Mississippian limestone has a pressure considerably lower than the other flows. This is indicated by the notes on the Voris well, which mention merely the fact that the water tapped at 317 feet overflowed, but records sixty-five feet as a minimum measure for the rise of the lower water. The height to which the upper flow rose in the Carter well is given as sixty-five feet above the curb, which would make the head about 530 above the sea level. In the Glen Oak park well the same water rose to within six feet of the

curb, which would make the head 528 above sea level. From the appearance of the flows at the wells, it is quite evident that the pressure of this water is not equal to that of the water of the Niagara limestone. At the present time the Carter well has a head of only twenty feet.

The head of the Niagaran and Ordovician waters is nearly 600 feet above the sea. In the asylum well the lowest water rose to within thirteen feet of the curb, or to a height of 592 feet above sea level. The elevation of the curb of the Pekin well is 530 feet and the water originally rose to sixty feet above this. In the Peoria Mineral Company well the water is reported to have had a pressure of 120 pounds at an elevation of 475 feet above the sea. If the figure represents the height in feet to which the water rose above the curb, it corresponds exactly with the Pekin and the asylum wells, and this is probably the case. In most of the wells the original pressure has diminished in the course of years, owing, no doubt, to leakages in the upper part of the well. In some instances it has been found necessary to repair the casing in order to maintain a sufficient flow. The flow of the Peoria Mineral Company well is said to have noticeably affected the flow from the Glen Oak park well, and it has for that reason been shut off.

As the Niagaran and the Ordovician waters are separated by a thick formation of shale, it would be natural to find a difference in their heads. If there is such a difference here, it is probably not very great, for local observations fail to notice its existence.

The head of the Silurian and the Ordovician waters is high enough to make them flow on all of the lowlands along the Illinois river, including the extensive terrace flats south of Pekin, and also on the bottom lands of Farm creek, Kickapoo creek and of the two Lamarsh creeks, in Hollis township, north into Limestone township at least two miles. The Mississippian water will hardly furnish a reliable flow on the Illinois river terraces, at least not where these are highest, but it can be expected to flow everywhere on the lowest bottoms of the Illinois river and of the Kickapoo and Farm creeks, and also for a mile or two up from the river bluffs on the bottoms of the Lamarsh creeks.

## Uses of Waters.

The artesian waters are now used principally for drinking water and for baths and swimming tanks. The Pekin well, the Central park well and the Sulphur Water House Bathing Company's well each supplies water for swimming tanks. The hydrogen sulphide gas, which the Niagaran water contains, is believed by some to make this water particularly suitable for baths. The Voris well and the stock yards well are used to furnish water for drinking purposes and for stock. The Glen Oak park well, the Spring Hill well and the Pulsifer well furnish drinking water only, and the waters of the well of the Peoria Mineral Company are not now used for any purpose. The Carter's brickyard well is used for boiler water. The St. Peter water in the asylum well was for several years pumped and used for all purposes in the institution, but the supply began to be insufficient two years ago and it is now entirely discarded.

## TEMPERATURE OF WATERS.

The temperatures of the flowing waters are known only in four instances. These show an average increase with depth of 1.58° Fahr. for each hundred feet, if 50° Fahr. be taken as the temperature of the surface.

*Table Showing Rate of Increase of Temperature, with Depth.*

| | Depth of main flow. | Observed temperature. | Rate of increase of temperature per 100 ft. from surface. |
|---|---|---|---|
| Asylum well | 1,600 ft. | 78° | 1.75° Fahr. |
| Pulsifer well | 900 ft. | 65° | 1.66° Fahr. |
| Stockyards well | 850 ft. | 65° | 1.41° Fahr. |
| Sulphur Water House Bathing Co. well | 800 ft. | 62° | 1.50° Fahr. |

# MILLBRIG SHEET OF THE LEAD AND ZINC DISTRICT OF NORTHERN ILLINOIS

(By U. S. Grant and M. J. Perdue.)

## Contents.

## INTRODUCTION.

The area represented in this detailed map contains about 10¾ square miles, situated at the northern edge of Jo Daviess county. The following sections are included in the map: Sections 15, 16, 17, 20, 22, 27, 28, 29, 32, 33 and 34, town 29 north, range 1 east of the fourth principal meridian; sections 13, 24, 25 and 36, town 29 north, range 1 west of the fourth principal meridian. Of the first group, sections 15, 16, 17, 20, 29 and 32, and of the second group, section 13, are fractional sections.

This area is a part of the Upper Mississippi valley lead and zinc district, which has long been a producer of ores of these two metals. In the last few years mining and prospecting have become very active in this district. This increased activity is due to the rise in price of both lead and zinc and to the appreciation on the part of mining men that important bodies of zinc sulphide, with some lead sulphide, exist below the level of ground water. The earlier mining was mainly for lead ore and was chiefly done near the surface and above the level of ground water.

The general geology and ore deposits of this district have been discussed in a number of publications, of which the following are some of the more recent:*

H. F. Bain: Zinc and lead deposits of Northwestern Illinois; U. S. Geological Survey, Bulletin No. 246, 56 pp., 1905.

U. S. Grant: Report on the lead and zinc deposits of Wisconsin, with an atlas of detailed maps; Wisconsin Geological and Natural History Survey, Bulletin No. 14, X and 100 pp., 26 pls., 1906.

H. F. Bain: Lead and zinc deposits of the Upper Mississippi Valley; U. S. Geological Survey, Bulletin No. 294, xi and 155 pp., 16pls., 1906.

U. S. Grant and E. F. Burchard: Description of the Lancaster and Mineral Point quadrangles; U. S. Geological Survey, Geologic Folio No. 145, 14 pp., 4 maps, 1907.

This map of a small part of the lead and zinc district of Illinois is presented with the hope that it may be of service to those actually engaged in mining and prospecting in this vicinity and that it may also be of service to those who find use for any detailed map. This map is a continuation southward of similar maps made in Wisconsin. It is hoped that further maps in Illinois may be made in the future.

The value of such a map to the mining man depends to a considerable extent upon the information available when the map was made. This map contains information available to October, 1906. Drilling

*The second publication here listed contains a bibliography of the Upper Mississippi Valley lead and zinc district, and may be obtained from the Director of the Wisconsin Geological and Natural History Survey, at Madison. The other publications may be obtained from the Director of the U. S. Geological Survey, at Washington, D. C.

is being constantly done in this district, and the data from such drilling will give additional information as to the position of the base of the Galena dolomite—an important horizon in mining. The Illinois Geological Survey earnestly requests that any information of this sort —not only for the area included in this particular map, but also for the adjoining areas—be sent to the survey at Urbana, Illinois.

Only a brief sketch of the general geology and are deposits is here given. Detailed information concerning these and other features of the district may be found by consulting the publications already noted.

## Outline of the Geology.

The geological formations represented in this district all belong to the Ordovician or Lower Silurian system. They comprise the three following divisions, named in ascending order: Platteville limestone, Galena dolomite and Maquoketa shale.

The lead and zinc deposits are confined to the Galena dolomite and to the uppermost part of the Platteville limestone, although small amounts of lead and zinc have been found in the Maquoketa shale.

The rocks of this district are practically horizontal. There are, however, exceptions to this horizontality, and dips of a few degrees may sometimes be seen. Ordinarily, however, dips of these rocks are measured in feet per mile, rather than in angles. The particular horizon of importance in mining, and that upon which the altitude of the rocks is usually based, is the bottom of the Galena dolomite or the top of the Platteville limestone. This horizon is represented by structural contour lines on the map.

*Platteville limestone*—This formation is the lowest in the district and outcrops only in one locality, *i. e.*, along the Fever river, at the southeast corner of the area mapped. It comes to the surface here, due to a small anticline, and disappears beneath the river both to the north and to the south. This formation has been struck in drill holes, but ordinarily drilling stops at the top of the Platteville limestone. Its exact thickness in this district is not known from drillings. A few miles to the north, in Wisconsin, the thickness averages about fifty-five feet, and approximately that thickness can be counted upon in the district here mapped. The next underlying formation is the St. Peter sandstone, which carries considerable water.

The Platteville limestone may be divided into four divisions, as follows:

| | | Feet. |
|---|---|---|
| 4. | Limestone, principally in thin beds, and shale | 10 to 15 |
| 3. | Thin bedded, brittle, fine-grained limestone | 15 to 25 |
| 2. | Thick bedded magnesian limestone or dolomite | 15 to 25 |
| 1. | Blue shale, sometimes sandy | 1 to 5 |

In this district the uppermost member, *i. e.*, No. 4, is exposed, and also the upper part of the next underlying member. This upper member consists of thin beds of limestone with small layers of shale, the latter being sometimes almost lacking. The uppermost layer is

frequently a blue gray shale or clay. This is known as the clay bed, and its top is here taken as the line separating the Platteville limestone and the Galena dolomite. It is a horizon which is ordinarily easily recognized in drilling. While there are other shale beds, both in the Platteville and at times in the Galena, still this particular shale is associated, frequently above and always below, with layers of thin, glassrock like limestone and so can be recognized in drilling. Moreover, this shale, or clay bed, lies just below the oil rock beds of the base of the Galena dolomite.

The glassrock, or what is known as the true glassrock of the lead and zinc district, is part of this upper member of the Platteville limestone, and consists of a dense, very fine grained, hard, conchoidally breaking limestone which rings when struck with the hammer. It is light chocolate color when fresh and weathers rapidly to a white or light gray. The typical beds of glassrock are from 3 to 8 inches in thickness, and they are separated by thin partings of chocolate colored shale or oilrock. The lower beds at times have a peculiar mottled appearance. Together these beds of typical glassrock vary from about 18 inches to 4 feet in thickness, and form what is called in the district the main glass layer. Exposures of this glassrock are seen at the ruins of the old mill in the southwest quarter of Sec. 34, T. 29 N., R. 1 E.

The upper part of the Platteville limestone is frequently highly fossiliferous, containing abundant remains of various kinds of animal life. One bivalve shell is quite common, and is characteristic of this horizon, It occurs just above the main glassrock beds and below, or even included in, the layer of shale which makes the limit of this formation. This fossil is a brachiopod, known as *Orthis subaequata*.

*Gaena dolomite*—This is the main formation of the district, both in thickness, number of outcrops, and economic importance, for it carries the chief ore deposits. It averages about 235 feet in thickness, although the thickness varies within the limits of this sheet from 220 to 260 feet, the maximum thickness being reached in the northwest part of the sheet. The variation in thickness is possibly due to the unequal erosion of the upper part of this formation before the deposition of the overlying Maquoketa shale; or, in some cases the apparent variation in thickness may be due to the lack of information as to the exact position of the top of the formation. Outcrops in such cases are not common, and the definite base of the Maquoketa is not always easy to locate.

The Galena formation is essentially a coarse-grained, granular, crystalline, porus dolomite which weathers into exceedingly rough, pitted and irregular forms. Not infrequently the rock breaks down in a coarse dolomitic sand.

This formation may be divided into the following divisions:

| | | Feet. |
|---|---|---|
| 5. | Dolomite, earthy and thin-bedded | 30 |
| 4. | Dolomite, coarse-grained, thick-bedded, with a little flint | 60 |
| 3. | Dolomite, coarse-grained, thick-bedded, with much flint | 90 |
| 2. | Dolomite, thick to thin-bedded, coarse to fine grained, the lower 15 feet locally a limestone | 50 |
| 1. | Thin-bedded, fine-grained limestone and bluish shale interbedded with thin seams and usually one or more layers of chocolate-colored carbonaceous shale or oilrock | 2 to 10 |

This lower member is commonly not well exposed, and as a rule the amount of carbonaceous material here is not so abundant as farther north in Wisconsin. The base of No. 1 is regarded as the horizon of the true oilrock, which is a thin bedded, soft, carbonaceous shale, usually chocolate to black in color. In the Wisconsin district this bed of oil rock is from a foot to 4 or 5 feet in thickness and is a very marked horizon. In the district here mapped, however, as far as drill records seem to show, and as far as the exposures go, the oilrock is not a sharply marked horizon. But there is at the base of the Galena a thickness of a few feet of shale and limestone mixed in with small seams of this carbonaceous shale or oilrock.

The second division of the Galena is the one in which most of the ore occurs. In the main it is a coarse-grained dolomite free from flints. The lower few feet are, however, at times non-dolomitic and fine-grained and glassrock-like in character, and sometimes interbedded with thin beds of shale which is quite fossiliferous. An exposure of this member of the Galena may be seen at an old quarry on the west side of the Chicago and Northwestern Railway in the east half of Sec. 34, T. 29 N., R. 1 E.

The other members of the Galena limestone—especially the upper member—are not very well exposed in this district.

The Galena as a whole is rather free from fossils, but there are two horizons which are marked by a peculiar fossil known as the lead fossil or the sunflower coral—*Receptaculites oweni.* These occur more or less scattered through the formation, but are especially abundant at two horizons; first, at the top of the second member of the Galena formation, where they occur closely associated with the beginnings of the flints; and second, at another horizon at the top of No. 3 of these divisions of the Galena. In this upper horizon these fossils are more abundant than at the lower.

*Moquoketa shale*—This formation is not well exposed anywhere within the area of this map. It occurs on the higher ground along the turnpike running from Galena, Illinois to Hazel Green, Wisconsin, and runs out on the hills both east and west of this turnpike. The thickness of this formation in the Upper Mississippi Valley lead and zinc district is about 200 feet, but within the area here mapped the greatest thickness does not reach half of that amount, the upper part of the formation having been removed by erosion.

The Maquoketa consists essentially of bluish and greenish shales, mingled with some thin beds of earthy limestone. The very base is a layer, one to three feet in thickness, of shales which contain an abundance of small fossil bivalves. These fossil shells *(Ctenodonta fecunda and Clidophorus neglectus)* resist weathering much more strongly than does the material which encloses them, and consequently they remain after the rest of the rock is decayed. It is by means of these peculiar fossils, which occur along gulleys or along the sides of roads, that the base of this formation is commonly located. Drilling through this formation does not seem to have been undertaken in this area.

## ORE DEPOSITS.

The ores of this district are those of lead and of zinc. The original ore minerals are lead sulphide (galena) and zinc sulphide (sphalerite); with these are varying amounts of iron sulphide (usually marcasite). Above the level of ground water the galena has been very slightly altered, showing a little change on the surface to lead carbonate, while the sphalerite has almost completely altered to a carbonate of zinc, known as dry bone or smithsonite, The earlier mining in this district was done mainly above the level of ground water, and the ores were galena and smithsonite. The mining of to-day and the future will be largely below the level of ground water, and the ore materials are the original metallic sulphides—galena, sphalerite and marcasite.

The ore deposits occur in several forms, which may be grouped under the headings of (1) crevice deposits, and (2) disseminated deposits. Crevice deposits are the common ones, and they take the form of vertical fissures and at other times of horizontal and inclined fissures, these latter giving rise to the common deposits known as flats and pitches, for which the district is famous. In these crevice deposits the ore is frequently arranged in layers, from the wall rock out, in this order; first, marcasite; second, sphalerite, with a little galena; third, galena in large crystals. This third layer is usually lacking in the deeper parts of the mines some distance below the level of ground water. The disseminated ores occur mainly near the base of the Galena formation, and are simply beds of limestone or shale which have been more or less thoroughly impregnated with the metallic sulphides.

The ores occur essentially in the Galena formation and the very upper part of the Platteville. In general the vertical crevices occur in the upper half of the Galena dolomite, while the flats and pitches, which form the main ore horizons of the district, are in the lower half, or more usually in the lower quarter of the Galena formation. The disseminated ore occurs near the base of the Galena formation and also in the upper part of the Platteville, although within the immediate district of this map no deposits in the Platteville seem to have been reported. They do occur, however, a short distance to the north in Wisconsin.

*Prospecting*—A few suggestions may be offered which it is hoped will prove of use to those engaged in prospecting for ore deposits in this district. At the present time it might be said that most any piece of land in the lead and zinc district is a feasible place for prospecting for ore deposits. That ore deposits, however, will be found in every such piece of land is highly improbable. From the past history of mining in the district and from our present knowledge of the structure, the origin and the relation of the ore deposits, three rather definite rules for prospecting can be formulated.

First. In the present state of development it is always wise to select for prospecting land which has in former years furnished considerable lead, or lead and zinc, ore above the level of ground water. Such districts can be recognized usually by the character of the surface, which has been more or less completely honeycombed with old

workings. While it is not possible to say that deeper ore deposits will be found only, or always, below these higher deposits of altered ores, it still is an almost universal rule that the deep deposits which are being worked today underlay deposits which were worked in years gone by.

Second. As the principal ores of the district, which are at present being mined, or which will be mined in the future, are the original metalic sulphides, these must be searched for below the ground water level. It is therefore wise to select land in which there is considerable thickness—30 to 50 feet—of the Galena limestone below the level of ground water. In the district which is here mapped, however, practically all of the land, except that immediately adjacent to the outcrop of the Platteville limestone, it is so situated.

Third. The best ore deposits are known to occur in synclinal basins, either at the bottom or along the sides of such basins. It is wise, then, to select an area which has this peculiar synclinal structure. If below any particular synclinal there is a considerable thickness of oil rock, then the chances here are still better, for the oil rock seems to have played an important part in the formation of these basins as well as an important part in the formation of the crevices and in the precipitation of the ores. The structural contour lines on the map show the relations of these synclinal basins. One of the most marked runs approximately east and west through the centers of Sections 21 and 22, T. 29 N., R. 1 E. Just to the south of this is a slight anticline, and then still farther south is a broad synclinal basin occupying most of the northern half of Sections 27, 28,and 29, T. 29 N., R. 1 E., and Sec. 25, T. 29 N., R. 1 W. It will be noted that practically all the old workings and the present workings are along either one of the synclinal basins already mentioned. Workings also occur along the northern slope of the first mentioned synclinal basin, and ore deposits may also occur in minor synclines which the map does not show because of lack of detailed information. Another synclinal basin, thus far little worked, is that which is shown on the map as running east and west through the north half of Sections 32, 33 and 34, T. 21 N., R. 1 E.

## Explanation of the Map.

The detailed map (folded in pocket) which is here presented, shows various features which may be grouped under the headings of topography and geology. Explanations of the method of representing these features on the map are here given.

*Topography*—The topographic features shown on the map may be grouped into three classes, as follows: (1) water, including streams, ponds, springs, ete.; these are shown in blue; (2) features of an artificial nature, such as roads, railroads, villages, mines, prospects, etc.; these are shown in black; (3) elevations and inequalities of the surface; features of this character are shown in brown.

All elevations are referred to mean sea level. Series of level lines were run along the principal roads, and the heights of many points, especially road intersections, were thus accurately determined. These

points are known as temporary bench marks and are commonly indicated by blazes on fence posts or telephone poles. Such bench marks are shown on the map by small black crosses followed by brown figures showing the elevations above sea level.

From the data obtained by leveling, supplemented by the use of the aneroid barometer, a series of contour lines were drawn. Such lines connect points of equal elevation above sea level and are drawn at regular vertical intervals. On this map the contour interval is ten feet, and the 50 and 100-foot lines are made heavier and numbered. By means of such contour lines the form of the surface of the land and the steepness of slopes, as well as the elevation of the surface, is shown. This may become more evident by consulting a sketch (figure 31) of an ideal landscape, which represents the sea in the foreground

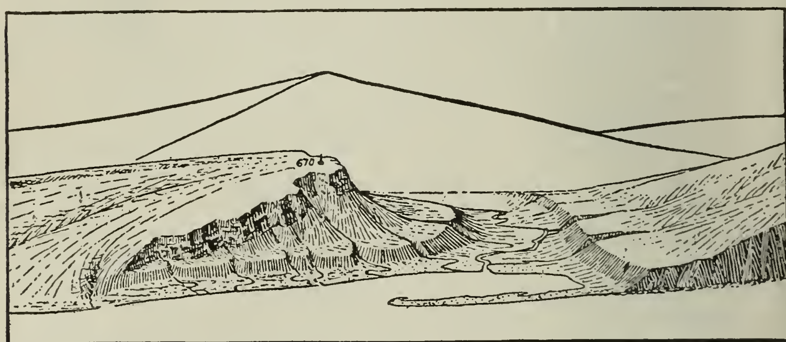
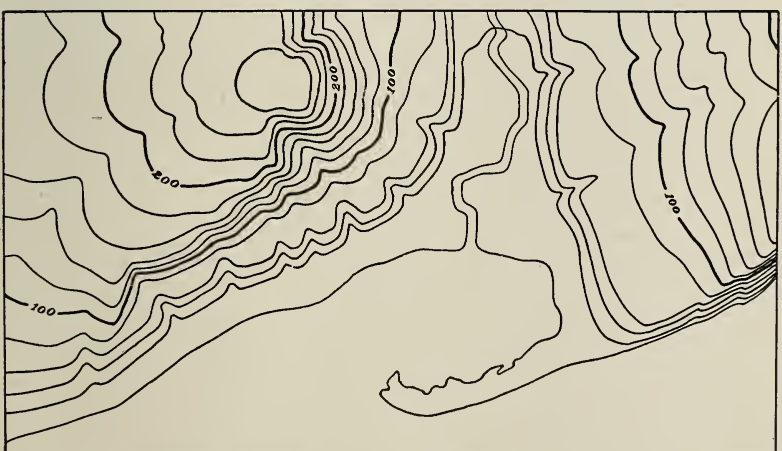



FIG. 31. Sketch of an ideal landscape. Reproduced by permission of the Director of the U. S. Geological Survey.

and a river coming into the sea. The immediate river valley is flat-bottomed and is bounded on each side by steep slopes, above which the land rises quite gradually on the east, while on the west there is an almost precipitous rise to the top of a hill. The western side of this hill has a gentle slope. Figure A of plate 23 shows a model, viewed directly from above, of the same landscape, and on this model lines have been drawn connecting points of equal elevation. In figure B of plate 23 the above lines are shown alone; this figure is a contour map (contour interval here is 20 feet) of the district shown in the ideal landscape (figure 31) and in the model (figure A of plate 23) of this landscape. Where slopes are steep, as on the west side of the river valley, the contour lines are close together; and where slopes are more gradual, as east of the river, the contour lines are farther apart, and are equally spaced if the slope is uniform.

To refer definitely to some point on the map, take the junction of the roads near the southwest corner of Section 33, T. 29 N., R. 1 E. Here there is a temporary bench mark, shown by a black cross, the elevation of the bench mark being 882.44 feet above sea level. The elevation of the ground at this point is something more than 880 feet but less than 890 feet. Going west along the road from this road junction, the ground is very level and it continues so with slight inter-

*a.* Model of Ideal Landscape.




*b.*. Topographic Map of Ideal Landscape.

ruptions through the next section to the west. The highest point reached by the road in this latter section is near the center of the section where it goes somewhat above 890 feet. Returning again to the same road junction as above, and going north, it is seen that the road descends rather gradually for about one-half mile and then, in a distance of less than one-fourth mile, it descends over 100 feet into the valley of the stream which enters the Fever river just west of Millbrig.

*Geology*—The rock formations which outcrop in this district are three in number and the areas in which each formation actually comes to the surface, or immediately underlies the soil and decayed material of the surface, are shown by appropriate color symbols. The Maquoketa shale, the most recent of the formations in this district, occupies only the higher portions of the area. The main part of the area, and especially the valley slopes, are occupied by the next underlying formation, the Galena dolomite. The lowest formation, the Platteville limestone, occurs only near the southeast corner of the map. The boundaries between these formations are indicated by dotted black lines.

In addition to the distribution of these formations, the geological map shows the altitude and attitude of the base of the Galena dolomite by means of a series of structural contour lines (green in color.) The arrows on these green lines indicate the direction of the dip of the rocks.

Starting at the Wisconsin State line in Section 16, T. 29 N., R. 1 E., and going southward, a green line, marked 660, is soon crossed. This line indicates that the bottom of the Galena dolomite is here 660 feet above the sea level. The arrows show that the rocks are dipping toward the south. On continuing southward past the Unity Mine the base of the Galena dolomite continues to descend until, near the center of Section 21, T. 29 N., R. 1 E., it is something less than 630 feet above sea level and then descends again at the south edge of this section to less than 620 feet.

By means of the contour lines (shown in brown) and the structural contour lines (shown in green) it is possible to determine how far it will be necessary to drill at any particular point to strike the base of the Galena dolomite. For instance, in the bottom of the valley immediately north of the center of Section 21, T. 29 N., R. 1 E., the contour lines show that the bed of the stream is approximately 745 feet abov sea level, while the structural contour lines show that the base of the Galena dolomite is here a little less than 630 feet above sea level, or approximately 627 feet. The difference between these two figures (i. e. 745 and 627 feet), or 118 feet, will give the approximate depth to the base of the Galena dolomite at this particular point.

# CONCRETE MATERIALS PRODUCED IN THE CHICAGO DISTRICT.*

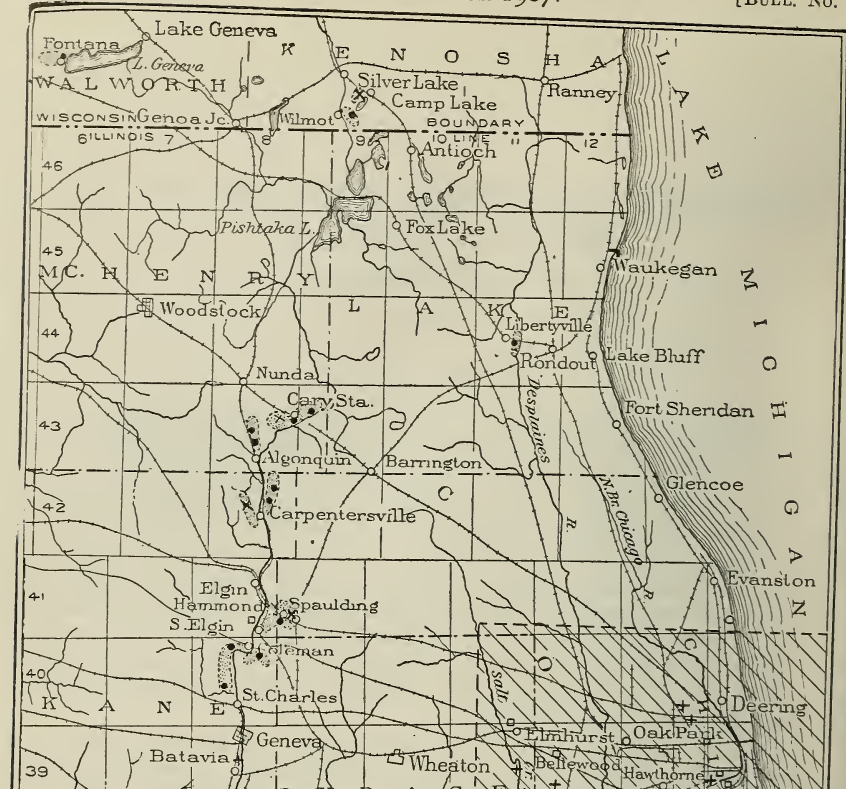
(By Ernest F. Burchard.)

## Introduction.

In connection with laboratory studies of the structural materials of the United States at the structural-materials laboratories of the United States Geological Survey in St. Louis, the writer spent several weeks in Chicago and vicinity, in the summer of 1906, obtaining representative samples of concrete materials. The location, extent, and geological relations of the deposits sampled were noted, so as to supplement the experimental data obtained, and a general familiarity with the processes of preparation of material was gained. When the more important laboratory work on the concrete materials of this district shall have been completed a separate bulletin on the subject will probably be published. The present paper consists mainly of abstracts from the text of the proposed bulletin.

The term Chicago district as used in this paper is applied to the area in northeastern Illinois and southeastern Wisconsin in which concrete materials are produced principally for the Chicago market. The main portion of the district is bounded rather definitely on the east by the Illinois-Indiana state line; on the south by an east-west line passing about seven miles south of Joliet; on the west by the west line of Kane and Kendall counties, and on the north by an east-west line passing just north of Lake Geneva, Wis. The area thus embraced is a quadrilateral 80 miles from north to south and 55 miles from east to west. About 500 square miles of this quadrilateral lies in Lake Michigan, so that there remains as land area about 3,900 square miles. (See fig. 32.) Councrete materials used principally in the Chicago market are produced also at three places beyond the area thus outlined, viz, Kankakee, Ill., and Beloit and Janesville, Wis. In a city having more than 2.000,000 inhabitants it is to be expected that a great deal of structural material such as dimension stone, granite blocks, clay for bricks, tile, an terra cotta, as well as limestone, sand, and gravel for concrete purposes should be brought from considerable distances. The significant fact has been brought out, however, during a brief study of the field, that Chicago and her environs, included within the area described above, produce practically all the concrete material that is

*From U. S. Geol. Survey, Bull. 340. Reprinted by permission, with the addition of data on tests furnished by the Testing Division of the Bureau of Engraving, of the City of Chicago.




| | | | |
|---|---|---|---|
| Main outcrop area of Niagara limestone in Desplaines Valley | Principal areas worked for gravel and sand | + Isolated rock outcrop, not quarried at present | Stone quarries |
| × Gravel and sand pits | Stone quarry and crusher | • Gravel pit, crusher, and washer | Gravel and sand pump |
| Area of the Chicago folio | | | |

FIG. 32. Map of main portion of district from which Chicago derives concrete materials. (From U. S. Geological Survey.)

used locally, besides nearly all the ordinary dimension stone and common clays. The granite, marbles, and finer grades of dimension stones, flagging, curbing, and fire clays are brought from various outside states. The granite areas near Green Lake, Wis., the limestone area near Bedford, Ind., the sandstone area near Berea, Ohio, and the clay mines of Illinois, Indiana and Ohio, are all important contributors to Chicago construction work.

The importance to Chicago of a near-by and adequate supply of raw materials for concrete purposes is very great, especially as concrete construction in its various forms is at present making more rapid advances than any other type of such work.

## Constituent Materials.

### VARIETIES.

The concrete materials produced in the Chicago district consist, in the order of quantities produced, of crushed magnesian limestone; sand, gravel, part of which is crushed; and Portland and natural cements. The crushed stone constituent closely approximates dolomite in composition, and is derived from the Niagara formation, which underlies the entire district; either outcropping at the surface or lying below thicknesses of glacial drift ranging from a few feet to 125 feet. The sand and gravel are derived from three types of material—(*a*) glacial drift and outwash from the drift sheet, (*b*) shore deposits of the present Lake Michigan, and (*c*) deposits on old beaches of the former extended glacial lake. Cements, though manufactured at Chicago, are not strictly of local materials, the limestone that enters into their composition being brought from Fairmount, a point in east-central Illinois about 100 miles south of the district as defined in this paper.

### VALUE.

It has proved difficult to ascertain exactly the value of the various materials produced in the Chicago district that are used in concrete work, for the reason that in making returns producers are not always able to state definitely the uses to which the whole of their output of broken stone is put. However, if we consider as concrete material all the crushed stone produced, except that sold for flux and for lime burning, the approximate value of this material produced in the district in 1906 was nearly $2,000,000. The value of sand produced during the same period was $205,500, and that of the gravel was $198,034. The total value of these concrete materials was therefore a little less than $2,500,000. Returns for 1907 are not yet avaiable, but it is likely that the figures for that year will not exceed those of 1906, as general building operations were greatly curtailed during 1907. The extensive construction work at the new town of Gary, Ind., being built by the United States Steel Corporation, probably offset in part at least the general inactivity in Chicago, the stone for Gary being almost wholly derived from the Chicago district.

## DETAILED DESCRIPTION OF MATERIALS.

### NIAGARA LIMESTONE.

#### *Character and Distribution.*

The Niagara limestone of the Silurian system underlies all but the southwest corner of the district. It consists mainly of highly magnesian limestone, but contains some shale near the base. Under probably nine-tenths of the area the rock is covered by glacial drift and recent soil and alluvium, the total thickness of which, in places, is as great as 125 feet, although generally it ranges between 30 and 80 feet. The exposures of Niagara rock are mostly in the southeastern quarter of the district as defined in this paper, and they are due (*a*) to irregularities in the bed-rock surface, (*b*) to stream erosion, or to a combination of these two causes. The preglacial surface or bed-rock topography was undulating as compared with the present flat plain upon which Chicago stands, and the ancient hills of limestone are consequently buried by a less thickness of drift than the valleys—in fact, in several places these limestone hills reach the present surface.

Within the city limits of Chicago there are ten or more places where the limestone either is exposed in a small area or else has been found to be so thinly covered by drift that stripping and quarrying are practicable. West southwest, and south of the city there are 25 or more small, isolated exposures, at most of which quarrying is now or has been carried on.

The main outcrop area in the district extends along the valley of Desplaines river from Sag Bridge to a point ten miles below Joliet. Here the rock forms the valley floor, overlain in places by a few feet of alluvium or by outwash sand and gravel, and in places it rises 30 to 50 feet in the bluffs. A few exposures occur also along other streams within the district, such as Salt creek near LaGrange, DuPage river near Naperville, and Fox river at Batavia, St. Charles, and South Elgin. (See map, fig. 32.)

The total thickness of the Niagara formation in the district ranges from 250 to more than 400 feet, and it is probable that the original thickness was greater than this, because there was opporunity for preglacial erosion of beds lying above the present surface.

The character of the rock at the various outcrops and quarries within the area covered by the Chicago geologic folio is described in that folio by William C. Alden.* Since the folio was published important new quarries have been opened within that area, particularly at Gary, LaGrange and McCook.

Just southeast of LaGrange, on the northeast side of the Chicago Junction railway, are the quarries of the Federal Stone Company and the LaGrange Stone Company, both of which have been opened within the last two or three yeas, and are about 20 feet deep. The strata do not outcrop at this place, although they approach within a foot or two of the surface, where the cover is thinnest. The surface of the rock

*Description of the Chicago district: Geologic Atlas U. S. folio 81, U. S. Geol. Survey, 1902.

is uneven, and a short distance to the east and northeast the cover becomes too thick for stripping. The rock has generally a slight dip to the southeast, but in places dips as steep as 20° were noted. The top rock is rather thin bedded, and generally is oxidized to a buff color two to ten feet below the surface, but is fairly white below the oxidized zone. The composition of the rock is shown by analyses four and five on page 355.

A new quarry was being opened near McCook in the summer of 1907 by the United States Crushed Stone Company. The stripping is thin and when removed discloses beds that are much fractured and weathered to a light buff color the full length of the opening, about 15 feet. Work is being pushed at this quarry, the excavation being facilitated by use of a steam shovel. Clay pockets are encountered in places in the limestone. The product is crushed and sold at present mainly for fluxing material. The average analysis (No. 7, p. 355) indicates the composition of the rock, and illustrates the fact that, although the material may be uniformly of a buff color, rather than white, it is quite as free from impurities as the unoxidized beds found at greater depths.

From the analysis which is submitted by the stone producers the rock is seen to be a fairly pure magnesian limestone, closely approximating the composition of dolomite, and therefore highly desirable for fluxing purposes. On account of its buff color its value should not be less for concrete material, except where a very light colored stone is required for exposed construction. After the quarry reaches greater depth the lighter colored stone will be found.

At Gary, southwest of McCook, is the new quarry of Dolese & Shepard. In August, 1907, this opening comprised about 15 acres and showed a section about as follows:

*Section of Niagara Limestone at Dolese & Shepard Quarry, Gary, Ill.*

| | |
|---|---|
| Soil and drift | 6 inches to 4 feet |
| Magnesian limestone, buff colored, slightly stained and weathered into thin strata | 4 to 10 feet |
| Magnesian limestone, light grayish blue, ranging from fine grained and dense to fairly porous; the beds are thicker than the surface rock, reaching a thickness in places of 15 inches; a few clay seams are present where the bedding planes are irregular and in joint planes; fossils are abundant | 27 to 30 feet |

The rock lies almost horizontal, and is cut by two sets of joints nearly at right angles to each other and extending northeast-southwest and northwest-southeast. In the section are three or four bands of ligh pinkish-gray porous rock, 7 to 12 inches thick, that can be traced halfway round the opening or farther, and such rock is found to make the most excellent lime. Crushed stone, rubble, and flux are the principal products here, and lime is soon to be burned.

The composition of the rock at Gary is shown by analysis No. 8, page 355, which represents an average of 27 analyses, one being made each week throughout the last half of 1903, a total of 811 carloads having been sampled.

The following section represents a quarry at Lemont:

*Section of Quarry of Western Stone Company, Lemont.*

| | Ft. | In. |
|---|---|---|
| Soil | 1 | 6 |
| Magnesian limestone, thin bedded, cherty | | |
| Magnesian limestone, in beds about 1 foot thick; contains some chert nodules | 3 | |
| Magnesian limestone, similar to above, but in beds 10 inches thick | 1 | 8 |
| Magnesian limestone, massive, very cherty, in two beds of equal thickness | 2 | 5 |
| Magnesian limestone, sparingly cherty | 1 | 9 |
| Magnesian limestone, cherty, with "hackly" fracture, in four thin beds | 1 | 3 |
| Magnesian limestone, gray, fine grained, chert free, massive bed | 2 | 5 |
| Magnesian limestone, gray, fine grained, chert free, in two beds, 1 foot 5 inches thick | 2 | 10 |
| Magnesian limestone, fine grained, chert free, in one bed, called "Washington ledge" | 1 | 3 |
| Magnesian limestone, gray, fine grained, chert free, in two beds, 3 and 7 inches thick | | 10 |
| Magnesian limestone, gray, fine grained, chert free, one massive bed Water level of quarry. | | 3-11 |

The cherty beds at this quarry can not be used for dimension stone, but they make good road material and ballast.

On the north side of Desplaines valley, about three-fourths of a mile northeast of Lemont, the Niagara limestone rises 35 to 50 feet in the bluff at the qaurry of the Young Stone Company. Here the following section is exposed:

*Generalized Section at Quarry of Young Stone Company, Lemont.*

| | Ft. |
|---|---|
| Soil | ½ |
| Gravel | 3-4 |
| Magnesian limestone, thin bedded, weathered and fractured | 5 |
| Magnesian limestone, even, medium bedded, fine grained, buff non-cherty | 6 |
| Magnesian limestone, even, medium bedded, cherty, gray | 7 |
| Magnesian limestone, even, heavy bedded, cherty, light colored | 2 |
| Magnesian limestone, thin to medium bedded, fine grained, non-cherty | 6 |
| Magnesian limestone, heavy bedded, fine grained, non-cherty, light colored | 10 |

Rubble, dimension and crushed stone are quarried from these beds.

Down the river from Lemont to a point about 10 miles below Joliet, the Desplaines valley is cut in the rock so that exposures are numerous, both along the valley sides and in quarries, excavated in the valley bottom. The sanitary and ship canal of Chicago, extending nearly to Joliet, has been cut in the rock along this part of its course, and consequently a large quantity of broken rock is available here. This material is being gradually utilized for riprap, ballast, filling, and crushed stone. At Lemont broken stone from the spoil banks of the canal is being loaded on barges and carried to Chicago, where it is used in lake front improvement work at Lincoln park. Two miles below Lemont the Western Stone Company operates two crushers which are converting the rock of the spoil bank into concrete material, and the product is shipped to Chicago via the canal. The weathering of

the rock where it has been piled for ten years has not been great. The material is mainly hard and gritty, but the surface rock is, of course, oxidized on the outside. Some portions of the spoil bank naturally furnish rock that is preferable to that in other localities, depending on the texture and the amount of chert and of clay present.

For about three miles below Lemont the valley sides are lined with abandoned quarries, where excellent dimension stone was obtained in the days before concrete construction was extensively employed. The rock suitable for dimension stone, known to the trade as "Athens marble," is found in its best development at and near Lemont, although good beds of it are found as far south as Joliet. Quarrymen have applied the term "tame stone" to rock that is fine grained, smooth textured, even bedded, and non-cherty, and such rock makes the best dimension stone. They have likewise applied the term "wild rock" to rock that is irregularly bedded, breaks with a rough fracture, and contains argillaceous material or chert or both. Such rock often makes very desirable crushed stone, and although it had to be discarded before the area of concrete, it is now as valuable for crushing purposes as the "tame stone," and by some producers is held to be preferable, for some of it is found to yield on crushing a more nearly cubical fragment than the "tame stone," which tends to crack into thin chips when crushed.

Within the city of Joliet, and for two or three miles north and south from its center, the quarrying industry is active, about 15 important openings have been noted in September, 1907. On the west bluff of Desplaines valley, in the S. E. ¼ section 33, Lockport township, the quarry of the Commercial Stone Company shows the following section:

*Section of Quarry of Commercial Stone Company, near Joliet.*

| | Ft. |
|---|---|
| Soil | 1-2 |
| Gravel | 4-6 |
| Magnesian limestone, buff colored, weathered, thin bedded, and cherty | 5-9 |
| Magnesian limestone, light gray, even grained, in medium to thick beds, with a few cherty strata near bottom | 37+ |

These beds dip 2° to 3° N. W., and are cut by two very prominent sets of joints. One of these sets extends N. 40° E. and the joint planes are vertical, clean cut, or enlarged by solution, and are spaced at intervals of 46 to 50 feet. The other set of joints extends practically at right angles to the first set, but he planes are less regular and persistent, and they pitch steeply to the southeast. Water descending from the gravel above the limestone has opened numerous large channels through the rock, and many of these are filled with clay when opened in quarrying. Along one joint plane so much rock has been removed by solution that the upper beds have caved down into the opening. Rubble is the principal product of the quarry at present.

On the east side of the valley, about one-fourth mile south of the north line of Joliet township, a quarry and crushing plant is operated by the State penitentiary. The quarry is excavated below the level of the valley bottom, and shows the following section:

*Section at State Penitentiary Quarry, Joliet.*

| | Ft. |
|---|---|
| Black soil and limestone débris | 1-2 |
| Argillaceous limestone, thin bedded and flaggy, somewhat stained to buff or light brown color | 3 |
| Magnesian limestone in fine grained, medium thick, even beds | 5 |
| Magnesian limestone, rough grained, irregularly bedded, in medium thick beds | 3 |
| Magnesian limestone, hard, in thin to medium thick strata, irregularly bedded, with rough fracture and films of blue, hard, clay-like material distributed through the mass. The color of the rock is light pink | 6 |

The rock obtained here is used for road making throughout the State.

The Western Stone Company operates a large quarry near South Richards street, in the southern part of Joliet. In this and neighboring quarries the Niagara limestone is exposed for more than one-half mile along the Michigan Central and Elgin, Joliet and Eastern tracks to depths ranging from 15 to 50 feet. The following section shows the general character of the upper part of the rock and its cover at this place:

*General Section at Quarry of Western Stone Company, Joliet.*

| | Ft. |
|---|---|
| Soil, gravel, peat, and calcareous clay, with minute shells | 2-20 |
| Magnesian limestone, thin bedded, flaggy and weathered to yellow or buff color on top; the rock is even bedded and fine grained (tame stone). Lower beds become lighter colored and reach thicknesses of 2 feet | 17 |
| Magnesian and argillaceous gray limestone (wild rock) in rough surfaced, irregular beds, 1 to 3 feet thick, mostly chert-free | 10-15 |
| Beds similar to above, but thicker bedded, and containing a little chert in small nodules, as well as considerable bluish-green argillaceous materials on the pitted surfaces of the beds | 12-15 |

The "tame stone" is used for dimension stone, flag stone, and curbs. The "tame rock" is entirely crushed. It is very hard and crushes into well-shaped lumps.

The beds are jointed, the planes trending nearly due northwest-southeast and northeast-southwest. The first-mentioned joints appear usually to be inclined to the northeast, but those of the second set are more commonly vertical. There has been rather general though slight slipping of the strata on the northwest-southeast joint planes. The displacement reaches 2 inches in a number of places, and the downthrow is toward the direction of inclination of the joint plane, or usually toward the northeast. Where the hade, or inclination, is in the opposite direction the downthrow is there found to be in the direction toward which the plane is inclined, or, in other words, the miniature fault is everywhere a normal one. In working the rock advantage is taken of this general drop on the northeast side of the joint planes, as it is possible thus to pry loose and move slabs and blocks with greater facility than where there is no offsetting in the beds.

As nearly all the quaries at Joliet are comparatively shallow, few, if any, additional facts would be brought out by further descriptions. In general it is shown that cherty beds usually outcrop in the river bluffs, and that below these cherty beds there are alternations of noncherty "tame" and "wild" rock, and in places beds that are sparingly cherty at 25 feet or more below the level of the flood plain.

Southwestward down Desplaines Valley to the mouth of Rock Run the normal magnesian-limestone character of the Niagara remains constant, although exposures below the south line of Joliet Township are fewer because of the presence of gravel terraces in the valley. In the vicinity of Rock Run, however, and extending southeastward to the vicinity of Millsdale, is a bed of shale very similar to the Maquoketa shale that lies below the Niagara formation. About 11 feet of this shale is exposed at the pit of the Millsdale Pressed Brick Company on the edge of the valley one-half mile east of Millsdale station. To the southwest of and stratigraphically below this shale lies a coarse-grained, roughly weathering fossiliferus limestone. It is cherty and in places contains large numbers of calcite nodules. This rock is exposed in the wagon road near Desplaines river south of Millsdale, below the Atchison, Topeka & Santa Fe Railway culvert one mile southwest of Millsdale; in Rock Run just below the bridge of the Chicago, Rock Island & Pacific Railway; along Dupage river above the Rock Island Railway bridge, and at other places in the vicinity. Fossils collected from the exposure on Rock Run, where the relations of the limestone to the shale are very close, and from the Millsdale locality, were submitted to Dr. Stuart Weller of the Illinois Geological Survey, and were pronounced by him to be Niagara forms. The shale did not yield any fossils where examined. The limestone below the shale is very dissimilar to Niagara limestone. It bears some resemblance to the Galena limestone, but unless further detailed studies demonstrate the contrary, the rock must be considered as belonging to the Niagara formation, on the paleontologic evidence furnished by Doctor Weller.

From an economic standpoint this limestone below the shale bed can not be regarded as of present importance to the concrete industry for the following reasons: (*a*) Its texture is not sufficiently uniform, as it contains a mixture of calcite, magnesian limestone, and chert; and (*b*) its outcrop area is too remote for markets to enable it to compete with the better Niagara limestone, which occurs in practically inexhaustible quantities in more advantageous situations. Therefore the survey of the Desplaines Valley for limestone concrete material available to the Chicago market was terminated with Millsdale as its southern limit.

The thickness of the Niagara limestone in a city well at Ottawa street and Crowley avenue, Joliet, was reported by the city engineer to be 220 feet. Below this the record showed a bed of shale 140 feet thick (Maquoketa), and next below was 225 feet of limestone (Galena). There is thus at Joliet no record of a thin bed of shale toward the base of the Niagara.

On Fox river the Niagara rock was observed to outcrop at about six places, and inasmuch as no special search was made for outcrops in the gravel districts there are doubtless others. Two of these outcrops are on the east and west sides of Fox river about 1 mile north of the center of Batavia, and quarrying in a small way for local use has evidently been carried on here. Another outcrop was observed west of the river, in the northern part of St. Charles.

At South Elgin, on the west side of Fox river, the Niagara limestone comes to the surface of the valley bottom and is being exploited at the quarry of Magnus & Hagel. The rock occurs in thin beds with irregular, horizontal, wavy bedding planes usually coated with thin seams of bluish-green clay. The rock breaks with irregular rough fracture and is rather cherty. At 20 feet below the top there are 3 feet of beds in which the chert nodules are large and almost predominate in the strata. The material is typically a "wild rock" and is highly magnesian. The top 5 to 10 feet of beds are weathered and stained to a buff color. The rock is sparingly fossiliferous and in places contains crystals of dolomite and pyrite.

On the west branch of Dupage river, three-fourths of a mile southwest of the railroad station at Naperville, is a small area of Niagara limestone exposed by this stream. The rock has been quarried extensively here in former years, but the workings are now abandoned and the pits are filled with water. The cover that was stripped ranged in thickness from 4 to 15 feet, principally of drift, and the cuts west from 40 to 70 feet deep. The quarries formerly furnished bridge stone, dimension stone, rubble, and crushed stone. The rock was apparently used largely in the construction of the older buildings at Naperville. Much of the rock obtained was massive bedded and even grained, and some was evidently cherty.

## CHEMICAL COMPOSITION.

An important use to which the Niagara magnesian limestone is put in the vicinity of Chicago is as a flux in iron and steel making. Vast quantities of Lake Superior ore are smelted and the iron is converted into steel at the works of the Illinois Steel Company at South Chicago and Joliet. At Indiana Harbor, Ind., the plant of the Inland Steel Company has commenced operations, and the United States Steel Corporation is erecting works of such magnitude near the lake shore in northwestern Indiana that the construction of the new town of Gary has been begun. As the Lake ore contains a very low percentage of lime and magnesia, good fluxing stone is very much in demand and many working analyses of the Niagara rock are available. A few of these are given below:

*Analyses of Niagara Limestone.*

| No. | $SiO_2$. | $Al_2O_3$. | $Fe_2O_3$. | MnO. | $CaCO_3$.*a* | $MgCO_3$.*a* | $Na_2O$. | $K_2O$. | $SO_3$. | P. | S. | $H_2O$. | Authority. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.12 | 0.91 | 0.83 | ........ | 54.73 | 42.79 | ........ | ........ | ........ | 0.005 | 0.04 | ........ | Illinois Steel Co., Chicago..... |
| 2 | 1.23 | .55 | .37 | 0.03 | 54.04 | 42.96 | 0.19 | 0.14 | Tr. | ........ | ........ | 0.29 | U. S. Geol. Survey structural-materials laboratories....... |
| 3 | 27.27 | 5.63 | 1.62 | .02 | 33.50 | 27.95 | .02 | 2.94 | Tr. | ........ | ........ | .26 | |
| 4 | .40 | ........ | .40 | ........ | 59.40 | 39.80 | ........ | ........ | ........ | Tr | .04 | ........ | Mariner & Hoskins, Chicago.. |
| 5 | .70 | ........ | .90 | ........ | 53.41 | 45.22 | ........ | ........ | ........ | ........ | ........ | ........ | Featherstone Foundry Co., Chicago............ |
| 6 | 1.04 | .86 | .80 | ........ | 54.82 | 43.13 | ........ | ........ | ........ | ........ | ........ | ........ | Illinois Steel Co., Chicago..... |
| 7 | .28 | .31 | | ........ | 55.38 | 43.93 | ........ | ........ | ........ | ........ | ........ | ........ | Inland Steel Co., Indiana Harbor, Ind.......... |
| 8 | 1.10 | .93 | .86 | ........ | 54.68 | 42.84 | ........ | ........ | ........ | ........ | ........ | ........ | Illinois Steel Co., Chicago..... |
| 9 | 17.30 | 1.33 | .96 | ........ | 36.00 | 41.00 | ........ | ........ | ........ | ........ | ........ | 1.00 | J. V. Q. Blaney .............. |
| 10 | 1.99 | .63 | 1.15 | ........ | 53.73 | 42.13 | ........ | ........ | ........ | .014 | ........ | ........ | ........ |
| 11 | 1.90 | .64 | 2.08 | ........ | 52.61 | 41.84 | ........ | ........ | ........ | .012 | .054 | ........ | ........ |

*a* The lime and magnesia are here given in terms of the carbonate in order more readily to show how closely the composition of the rock approaches tha of dolomite ($CaCO_3$–54.35 per cent; $MgCO_3$–45.65 per cent.)

1. From Dolese & Shepard, Hawthorne quarry. Average of 18 analyses made on 878 carloads of stone in 1904.
2. From basal beds at quarry of Brownell Improvement Co., Thornton. Rock is burned for lime.
3. From beds near middle of face of same quarry at Thornton. Rock can not be burned for lime.
4. and 5. Samples average from top 20-foot face at quarry of Federal Stone Co., Lagrange.
6. From Dolese & Shepard, McCook quarry. Average of 36 analyses made on 803 carloads of stone in 1903.
7. From United States Crushed Stone Co., McCook. Average of 6 anaylses.
8. From Dolese & Shepard, Gary (Ill.) quarry. Average of 27 analyses made on 811 carloads of stone in 1903.
9. "Athens marble" from Lemont. Analysis furnished by Western Stone Co.
10. and 11. Averaged analyses from quarry of Joliet Flux Stone Co., Romeo.

GENERAL METHODS OF PREPARATION OF CRUSHED STONE.

As nearly all the stone quarries in the Chicago district are in the form of pits excavated below the surrounding surface, the problems that have to be met are those peculiar to this type of quarry, and therefore the same fundamental principles are very generally observed. Methods vary considerably, however, throughout the district, according to the size of the quarry, its stage of development, the character of the rock, and the uses for which it is intended. In the initial stage the rock must be stripped of its overlying cover of soil and glacial débris. This is usually done by means of scrapers, but in the case of deposits 5 or 6 feet thick a steam shovel may be advantageouly employed, particularly where the same shovel can be used for further work in handling the broken upper courses of rock. A thickness of 6 feet of cover is considered to be about the maximum limit profitable to strip at present. Drilling and blasting are universally employed to break up the rock, but here again occurs a wide diversity in practice. Both steam and compressed air are used in drilling, the latter preferably on long lines. The depth drilled ranges from 3½ feet to 24 feet. The charges also vary considerably in number, character, and strength. Most quarrymen use dynamite, although a few prefer black powder. The thoroughness with which the stone is broken up in blasting contributes toward the economical operation of a quarry. At some quarries large quantities of rock are shot out in huge blocks and these require reblasting and also a great deal of subsequent breaking with sledges to reduce the stone to a suitable size for the crusher. At one quarry, operated by an expert powder man, holes are drilled 2 feet apart, 4 to 10 feet from the face, in two rows, and set "staggering." At times as many as 100 shots are fired at once, and as a result very little reblasting is found necessary.

At practically all the quarries equipped with crushers, the crushers are situated at the surface, above the quarry, so that the rock has to be raised to them At the greater number of quarries the broken rock is loaded by hand and hauled in automatically dumping cars up an incline by cable. At a few of the larger but shallow quarries the rock is loaded by steam shovels. Rock for lime burning or for rubble is generally selected and loaded by hand. In very deep pits platform elevators are in use, so built that they carry one or two loaded cars at a time. The character and capacity of the tram cars vary according to the general character of the equipment of the quarry, cars of wood or steel that hold 2 to 3 yards of broken stone being used. In crushing the stone several types of equipment are employed, but each aims to break the stone and to separate it into definite sizes by dry screening. For concrete purposes the stone should be as free from dust as it is possible to make it, and therefore plants which pay especial attention to the screening end of the process produce the best grade of concrete material.

One of the largest and most efficient plants in the district consists of two mills, one equipped with a No. 8 and the other with a No 7½ Gates gyratory crusher, besides two No. 5 crushers each. The capacity of the two sets of crushers is respectively about 200 tons and 170

tons per hour, giving an average daily output of about 3,000 tons. The rock is put through rotary cylindrical steel screens, that give the following sizes: "Screenings," less than one-fourth inch; "roofing," one-fourth to one-half inch; "concrete," one-half to 1 inch; fine medium, 1 inch to 1½ inches; "medium," 1½ to 2½ inches; macadam, 2½ to 5 inches; and fluxing stone, 5 to 7 inches, the last size being rejected by the coarsest screen. Crushed stone is screened dry as contrasted with the washing process to which gravel is subjected when crushed and screened. As a rule the broken stone comes from the quarry with little or no foreign material, and whenever a clay seam or pocket is encountered it is cheaper to extract the material in the quarry than to remove it by washing at the mill. Another large, newly built plant is equipped with one No. 8, two No. 5 and two No. 3 crushers and four screens. The reported product of this mill at the start was 1,600 to 3,00 cubic yards * per day. One plant, equipped with one No. 7½ and two No. 4 McCuly crushers, is reported to average 700 to 800 cubic yards per day of stone in five grades ranging from seven-eighths inch to two inches, besides screenings. Still another system of crushers in use is the Austin. At a plant equipped with one Austin No. 7, one Austin No. 4, one Gates No. 3 crusher and two screens, the capacity per day is reported to be 300 yards.

## Available Limestone.

The reserves of Niagara limestone in the Chicago district suitable for crushing into concrete material are practically inexhaustible. The supply in those city quarries that are hemmed in by streets and buildings is of course limited because city values will prevent areal enargement of the pits, and they must be sunk deeper until they reach the limit of depth beyond which it is impracticable to raise rock, or until they reach the underlying shale. It is thought that the deepest quarries still have more than 100 feet of stone below their lowest levels, so that their continuation is mainly a question of costs, and in such quarries slightly increased costs of working are offset by central location and consequent decrease of cost of delivery to consumers.

In the discussion of the Niagara formation the distribution of available material has been outlined in connection with the description of working quarries. The main areas are shown on the map (Fig. 32). The Desplaines valley will probably aways continue to furnish the greater supply of crushed stone, although there is room for much more excavation at Stony Island, Blue Island, Thornton, Lagrange, Naperville and at points on Fox river.

*Sanitary and Ship Canal Spoil Bank*—The broken stone along the rock-cut portion of the sanitary and ship canal constitutes an important stock of material that is available without having to be quarried. Tests of this material made by the Chicago city engineering department show that although the rock tested was necessarily taken from the outside, or weathered portion of the spoil bank, the character still remains good, and it must reasonably be expected that on the inside of the

*The cubic yard is regarded as equivalent to 1¼ short tons.

pile also it should be sound. (See page 351.) From Willow Springs to Lockport, a distance of 15 miles, the channel is cut through rock. It is 160 feet wide at the bottom and 162 feet wide at water line, and the depth in this section averages 35 feet. The grade of the channel is 3¼ inches to the mile. The walls in the rock cut, having been cut by channeling machines, are smooth and perpendicular, with offsets. The total amount of solid rock that has been excavated is estimated by the engineers of the sanitary district to aggregate 12,912,000 cubic yards. When broken up by blasting and piled in minature mountain masses along the borders of the channel, the cubic contents of the material was largely increased. After nearly eight years of construction work, water was turned into the canal January 2, 1900, and for several years afterwards these mountains of stone piled along the right of way were regarded simply as an incumbrance. Recently it has been planned by the sanitary district board of trustees to turn this incumbrance into an asset by selling the broken rock to parties who will erect crushers and convert it into stone for concrete, paving, etc.

The board has estimated that there are about 20,000,000 cubic yards of stone in these piles—material enough to construct concrete docks from the mouth of Chicago river throughout the length of the canal, Desplaines and Illinois rivers to St. Louis, following the course of the proposed inland deep waterway, or else the material could be used to construct a chain of concrete factory buildings and warehouses from Robey street, Chicago, where the canal begins, to Joliet, 40 miles inland. The price basis on which the rock is to be disposed of by the sanitary district is 10½ cents a yard and a portion of the net profits.* A beginning has already been made toward utilizing this spoil-bank stone. As mentioned on page 351, the Western Stone Company is operating two crushers near the county line west of Lemont, and east of Lemont the broken stone is being removed from the bank by steam shovel and shipped. without crushing, via barges on the canal to the lake front at Lincoln Park, Chicago, where it is used for riprap. This rock compares favorably in quality with freshly quarried limestone.

*Importance to proposed deep waterway*—All the available rock, both in the spoil bank and in place in the Desplaines Valley, is adjacent to rail and water transportation facilities and can be cheaply handled. These facts, in connection with the almost limitless reserves of high-quality stone, are not only of importance in assuring Chicago a plentiful supply of stone for crushing, but they have an important bearing on the economical construction of the proposed deep waterway from the Lakes to the Gulf. It must be remembered that most of its length the Illinois river, along which much concrete work would be necessary, flows through the coal measure area, cutting into soft shale and sandstone and exposing few limestone beds thick enough to quarry until the area of Mississippian rock is reached, near its mouth. Therefore supplies of crushed stone for concrete work would have to be

*From an industrial pamphlet issued by the sanitary district of Chicago, 1907.

obtained at the extremities of this inland waterway, and the Chicago end may be said to be well prepared to furnish the larger share of the needed material.

## GLACIAL SAND AND GRAVEL (OUTWASH AND MORAINE MATERIALS.)

### CHARACTER AND DISTRIBUTION.

Another source of concrete materials in the Chicago district may be found in the sand and gravel of glacial origin, derived mainly from the drift of Wisconsin age. The deposits here considered lie mainly within the morainal areas, but the character of many of the deposits is that of outwash material—that is, nearly clay-free, stratified gravel and sand, as distinguished from the morainal material, which is composed of clay, bowlders, and sand mingled in a confused mass. While the moraines of the Wisconsin drift sheet in northeastern Illinois and southeastern Wisconsin were being formed, there were streams of water issuing from the ice sheet and escaping to Mississippi river by way of Rock river and the tributaries of Illinois river, the Fox, Dupage, Desplaines and Kankakee. These streams became overburdened with sand, gravel, and silt derived from the glaciers, and as a result filled up their beds and valley bottoms to a greater or less extent. In some places they spread out the detritus in terraces, or subsequently cut a new channel through the filled-up valley, leaving residual terraces on the valley sides.

The principal deposits of this type which are of economic importance in the Chicago district are situated, as shown on the map (fig. 32), along Fox river between Camp Lake, Wis., and St. Charles, Ill.; on Desplaines river at Libertyville and at and below Joliet, and on Long Run, Spring Creek, and Hickory Creek, small eastern tributaries of Desplaines river near Joliet. Beyond the area on the map, in the valley of Rock river, outwash deposits are exploited for the Chicago market at Janesville, Wis., and in Winnebago county, Ill., one mile south of Beloit, Wis. Besides these outwash deposits there is a thick deposit of morainal gravel being worked at Fontana, at the west end of Lake Geneva, Wis.

The important Fox river sand and gravel deposits in Illinois are near Cary, Algonquin, Carpentersville, Elgin and St. Charles, and the general characteristics of the deposits being worked may be indicated by descriptions of a few typical workings. At Cary the deposits form a terrace on the north side of the river both east and west of the Chicago and Northwestern Railway, and are worked by the railway and the Lake Shore Sand Company. East of the railway the Lake Shore Sand Company has opened a face nearly one-half mile long. The present workings are at the northwest end of the face and disclose a bank about 40 feet high. The material ranges from fine quartz sand to bowlders, a few of which are 18 inches in diameter or larger. The bank is reported to average 75 per cent sand and 25 per cent gravel, including everything larger than torpedo sand. The upper 25 feet of the bank carries more gravel than that below, and in the middle third is found the coarsest gravel. There are a few ledges of partly consolidated gravel conglomerate, and locally near the base of the cut is

4 to 6 feet of sand that has been indurated by a dark furruginous cement, forming a sandstone. Such hardened crusts of sand and gravel are termed by the quarrymen "hardpan" and this material has to be discarded, as the pit is worked by steam shovel and the hardpan ledges can not be cut by the shovel nor economically broken by blasting. West of the Chicago and Northwestern Railway the Lake Shore Sand Company is working a pit about 75 feet deep, below which water and quicksand are encountered. The material here runs irregularly as to its content of sand and gravel, but will probably yield a higher percentage of sand than the bank east of the railway. The middle third (vertically) will probably yield 75 per cent of sand, the upper part a little less, and the lower part a great deal more. The character of the material varies greatly from place to place, lenses or pockets of sand and gravel occurring without apparent system. For instance, on the southeast side of the present pit there is a bed of fine sand, extending 30 to 40 feet above the bottom, whereas on the opposite side of the pit alternate layers of gravel and sand extend down within 10 or 15 feet of the base. At this cut there is apparently no "hardpan" present, a fact which also illustrates the variability of the local deposits.

For two and one-half miles north of Algonquin sand and gravel are found on the sides of the small valley through which the Chicago and Northwestern Railway passes. Northward toward Crystal Lake the deposits of sand and gravel are reported to grow thinner. The deposits at present worked form the shoulder or border of the upland lying between this small valley and Fox river to the east. At the bank of the Aetna Sand and Gravel Company, about two miles north of Algonquin, the heaviest deposit of sand and gravel is about 50 feet thick, with 2 to 4 feet of soil above the reddish clay below. This clay floor is about 25 feet above the creek bed. The banks worked here are from 20 to 40 feet thick, and they yield on an average about one-third gravel and two-thirds sand. The gravel runs rather small and contains only a few bowlders, which are found at the base of the deposit. At the top of the deposit and following the contour of its surface is a bed 5 to 10 feet thick containing an equal if not greater quantity of gravel than sand. Below this the gravel and sand are interstratified in layers from a few inches to 4 to 5 feet thick, and also are mixed together. Cross-bedding is seen at many places in the section and beds having this structure are so firmly consolidated by a calcareous cement as to form hard conglomerate or hard sandstone. In places this material has assumed tubular or "pipy" shapes. Such material softens with exposure but does not disintegrate entirely. The finest sand is nearly all made up of quartz and other crystalline rock, but gives some effervescence in acid. The coarse sand effervesces more freely, showing a large proportion of calcareous material. A carload of 1-inch gravel showed nearly 20 per cent (roughly estimated) of crystalline pebbles, the remainder being mainly dolomite with some chert.

On the east side of Fox river, one and one-half miles below Algonquin, is the pit of the Richardson Sand Company. The bank worked

here is in the top of 50 feet of the range of hills that rise 150 feet above Fox river at this place. A general section of the material exposed in the cut is as follows:

*General Section at Richardson Sand Company's pit near Algonquin.*

| | Feet. |
|---|---|
| Soil, dark brown | 1-4 |
| Gravel and bowlders, very coarse, in places 1½ to 2 feet in diameter | 10-12 |
| Gravel, medium sized, with a small proportion of coarse material partly cemented to hard conglomerate | 9 12 |
| Gravel, medium sized and streaks of cross-bedded sand | 8-14 |
| Sand, fine grained to torpedo, in cross-bedded lenses with pockets of gravel | 12-15 |
| Clay. | |

This deposit contains an unusual proportion of coarse material, some of the bowlders being angular slabs of Niagara dolomite so thick as to show more than one stratum. Many of the large bowlders are of crystalline rock. The above section can not be regarded as persistent, however, for the variation in the character of material from point to point is very abrupt. The yield of sand and gravel is about equal in quantity, although there is a larger proportion of sand than gravel in the bank. This is due to the fact that part of the sand is too fine to be caught by present methods of separation and is consequently washed away with clay and silt to the settling pond. When stripped, the surface of this gravel is almost level.

From Carpentersville to Algonquin on the east side of Fox river deposits of sand and gravel are found in placee, but not continuously. For much of the distance the clay which underlies the gravel rises high and lies nearly parallel to the contour of the hills, so that the gravel is too thin to be profitably worked. On the west side of Fox river valley there are also high bluffs, largely of clay, on top of which sand and gravel occur, but the deposits have not yet been worked because of lack of transportation facilities and irregularity in thickness of the material, and because the present demand is supplied from deposits more advantageously situated.

South of Elgin there are sand and gravel deposits worked on the west side of Fox river near Coleman and 1 mile north of St. Charles, and on the east side of the river at Hammond and 1½ miles east of Coleman.

Near Coleman, between the Illinois Central Railroad and Fox river, gravel deposits are worked by the Richardson Sand Company. At this pit the working face is 15 to 30 feet thick, although the clay which underlies the deposits has so uneven a surface that the gravels thin in places to 6 or 8 feet. Overlying the sand and gravel is 4 to 5 feet of fine-grained silt. The material being worked yields about three parts of sand and one part of gravel. The gravel is mainly small in size, and the sand is rather coarse, mostly a torpedo grade. The 1-inch to 1½-inch gravel appears to contain 10 to 15 per cent of crystalline material, and the finer gravel a still higher percentage. At the base of the deposit are many rather large bowlders of dolomite and granite, 2 to 3 feet in diameter. The sand and gravel instead of occurring in

separate strata as in the region near Algonquin, are rather uniformly mixed together, and no "hardpan" or consolidated conglomerate was noted.

East of the river and south of the Chicago, Milwaukee and St. Paul Railway at Hammond is the pit and plant of the Chicago Gravel Company. The sand-gravel deposit lies upon a clay floor that is slightly uneven. The deposit reaches a total thickness of 27 feet in places and the stripping averages about 2 feet. A few bowlders 2 to 3 feet in diameter occur at the base, but in the bank the gravel is unusually uniform in size, rarely running into large cobblestones. The sand is a good sharp torpedo, not very fine. It contains a small proportion of lime, reported to be about 2 per cent. The proportion of sand to gravel in the bank is said to average about 55 to 45. No conglomerate nor "hardpan" was noted, but lenses of clay were found to occur in the bank. One of these noted at the time of visit was 6 feet thick in a bank 22 feet in length. Most of this clay, fine-grained and silt-like material, can be kept out of the product by a skillfully manipulated steam shovel, although some of it is certain to be loaded with the sand and gravel and it cannot be eliminated entirely in the washing.

One mile north of St. Charles, on the west side of Fox river, is the pit of the American Sand and Gravel Company. The deposits here reach a thickness of 35 feet. Below the sand and gravel water is encountered in quicksand, before the underlying clay is reached. The base of the deposit is therefore low, not far above the level of Fox river and of the creek to the south of the pit. Gravel and sand in about equal parts appear to constitute the bulk of the material. The gravel ranges from small to course sizes, and some cobblestones go to the crusher in nearly every yard of material excavated.

Notes on the gravel pits along Fox river would not be complete without mention of two points just north of the State line in Kenosha County, Wis. At Capp lake are some abandoned pits owned by the Wisconsin Central Railway. The deposits here are reported to have been thoroughly prospected, but to have proved not to be of promising thickness nor cleanness. Below 2 to 3 feet of soil there lies about 5 feet of fairly good gravel in the higher parts of the bank. Below this there are alternate seams of clay and quicksand containing heavy bowlders. Washing and crushing would therefore be involved to too great an extent for practical purposes.

Near Wilmot, Wis., is a pit the output from which is taken by the American Sand and Gravel Company. The pit is a straight cut into a terrace of Fx river and shows the following section:

SECTION OF GRAVEL PIT NEAR WILMOT, WIS.

| | Feet. |
|---|---|
| 1. Soil | 1-2 |
| 2. Gravel and sand. The gravel is clean and contains about 15 per cent of crystalline rock, the remainder being dolomite. About 15 per cent of the gravel runs larger than 2 inches | 8-14 |
| 3. Quicksand and silt, very fine-grained material containing about 60 per cent of quartz, the balance being clay minerals | 14-15 |

| | |
|---|---|
| 4. Gravel, similar to the upper gravel bed (No. 2) | 20 |
| 5. Sand, fine grained, to quicksand. In the aggregate this bed is coarser than bed No. 3, contains a higher percentage of silica and less clay | 15 |
| 6. Quicksand and water. | |

The beds of quicksand inclosed in the gravel vary in thickness and do not conform in contour to the present surface of the terrace. In general they appear to dip toward the northeast and to pinch out in various directions as if lens-shaped. The material is reported to be composed of the various grades in about the following proportions:

PROPORTIONS OF SAND AND GRAVEL IN PIT AT WILMOT, WIS.

| | Per cent. |
|---|---|
| Concrete sizes, one-half inch to 1½ inches, of which about 20 per cent is crushed gravel | 20 |
| Roofing gravel, one-eighth inch to one-half inch, total | 20 |
| Sand, fine grained, with a small proportion of torpedo size. It is mostly quartz and fairly free from quicksand and clay | 60 |
| | 100 |

On the west side of Desplaines river at Libertyville is the sand and gravel pit of the Lake Shore Sand Company. The deposits seem to be mainly west of the river in this vicinity and are comparatively thin. This deposit is the thickest in the locality, and it ranges from 5 or 6 to 25 feet in thickness above water level. Test wells are reported by the operators of the pit to show 20 feet of gravel below water level. The water level varies 1 to 2 feet during the year, and the cut is deeper or shallower accordingly. A section made at the southeast end of the cut, where material was being obtained October 3, 1907, is as follows:

SECTION OF SAND AND GRAVEL BANK AT LIBERTYVILLE.

| | Feet. |
|---|---|
| Soil | 1-2 |
| Fine sand, loam, and a little gravel | 0-4 |
| Clay lens, saucer-shaped in profile | 0-1 |
| Gravel and torpedo sand in alternate beds, 1¼ to 2 feet thick, cross-bedding common. The gravel is mostly smaller than 4 inches. The proportion of sand to gravel ranges from 2 to 1 to 1 to 1, but will average close to 1.5 to 1 | 16-20 |
| Gravel, sand, and water (reported 20 feet to clay.) | |

The usual sizes of sand and gravel are produced here and an additional product worthy of note is the unwashed run-of-bank sand and gravel, including all material smaller than 1¼ inches that is used in road making. It is stated that the loam present exerts a cementing action that makes the material of value as a bond when laid in alternate layers with crushed stone in macadamizing roads. Unsuccessful efforts have been made to pump the sand and gravel that lie below water level, the result being that the pumps were soon choked by the gravel. It is proposed to attempt at some future time the dredg-

ing of these deposits. It would seem worth while to utilize these submerged materials, as the visible supply of gravel above water level is diminishing rapidly in this locality.

Farther down the Desplaines valley deposits of sand, gravel and bowlders are scattered at irregular intervals and many of these are worked from time to time in a small way for local purposes. One such deposit is about a mile north of Willow Springs. The main deposits, those that are at present affording material sufficient for the operation of crushing plants, are at and below Joliet. Hickory and Spring creeks have built up deposits of gravel in their valleys and in the Desplaines valley near the junction of the two creeks.

On east Washington street, Joliet, the Chicago Gravel Company operates a pit and crusher. The deposit varies greatly from place to place.

The gravel and sand are cross-bedded in places. The clay content of the gravel averages about 20 per cent. The gravel consists mostly of dolomite, with a few crystalline pebbles. In places the material is hardened by calcareous cement to a conglomerate. The sand is fine to coarse grained and of dark color. It contains comparatively a high percentage of limestone and dolomite grains and of clay, with relatively a low proportion of silica.

The clay seams thin out to the north and south. Characteristic of the bank on the east side of the pit are that no beds of fine sand appear in the section and that the gravels are more even bedded than elsewhere in the pit.

Another plant of the Chicago Gravel Company is on the east side of the valley about 1½ miles above Millsdale, adjacent to the Santa Fe and Chicago and Alton railways. The deposit worked here is in the form of a terrace or a bar in the Desplaines valley and consists of material ranging from sand and loam to bowlders 2 feet in diameter. The bottom of the cut is in gravel, but reaches ground-water level, which is practically at the level of the water in the river and fluctuates with it. The deposit is about 10 feet thick on one side of the cut and 20 feet thick on the other. The gravel and bowlders are composed principally of hard dolomite, but about 5 per cent of crystalline material is present. The loam and sand are highly calcareous. The sand and gravel deposits in this vicinity and southward to the mouth of the Dupage are extensive, and thus far have been only very slightly utilized.

Certain important deposits of sand and gravel which, although at considerable distance from Chicago, are so directly connected by railroads with the city that they are worked to advantage should be mentioned in these notes. Such localities are in southeastern Wisconsin, at Fontana, Janesville and Beloit.

At Fontana, at the west end of Lake Geneva, the Lake Geneva Gravel and Sand Company is exploiting a thick gravel bank. The deposit is part of the Darien moraine of the Delavan lobe of the Lake Michigan glacier, acording to Alden.* The maximum thickness of

*Alden, W. C., The Delavan lobe of the Lake Michigan glacier: Prof. Paper U. S. Geol. Survey No. 34, 1905, Pls. IV, X, and X.

the cut is about 90 feet. Two or three feet of soil is stripped from the top by means of scrapers. A general section shown by the cut is as follows:

General Section of Gravel Pit at Fontana, Wis.

| | Feet. |
|---|---|
| Soil with a few large bowlders at base | 2-4 |
| Clayey, loamy, fine sand, of brownish color, containing a little gravel | 6-7 |
| Coarse, cobblestone gravel | 20 |
| Sand, thin ledge | 1-3 |
| Gravel, rather coarse, with some sand, mainly concealed by talus to bottom of cut | 30-60 |

The gravel runs unusually large, as compared with the Fox river and Rock river deposits. In the larger gravel there is fairly large proportion, perhaps 15 per cent, of crystalline rocks, many of which are dark colored. The remainder of the gravel is mostly dolomite and limestone, largely of Niagara age. The proportion of gravel to sand is reported by the operators of the pit to run about 3 to 2, and in places a still higher proportion of gravel is found. At the west end of the pit there is considerable firmly cemented conglomerate.

There are apparently similar deposits still undeveloped in many of the hills at the west end of Lake Geneva, although none are so easily accessible as the bank just described.

Near Janesville, Wis., the outwash deposits of Rock River Valley and tributary valleys are worked for sand and gravel. On south Main street, about 1 mile southeast of the middle of Janesville, a sand and gravel bank is exploited for the manufacture of sand-lime brick, cement shingles, and concrete blocks and posts. The face of the bank is about 25 feet in height. The upper 8 to 10 feet carries sand and gravel in the proportion of about 5 to 3, but below this the ratio increases to about 10 to 1. The gravel is small, few of the pebbles exceeding 3 or 4 inches in diameter. The material is very clean, and the sand is rather fine and composed almost entirely of quartz.

On the line of the Chicago, Milwaukee and St. Paul Railway, about 2½ miles east of Janesville, is a sand and gravel bank worked by the Knickerbocker Ice Company. The face of the bank is 50 to 70 feet in height. The material consists of small, clean gravel and clean quartz sand, much of which is of rather fine grain. The upper half of the bank is reported to carry sand and gravel in about equal quantities, but in the lower part sand predominates in the ratio of about 5 to 2. The sand occurs in beds of fine to torpedo size and in beds with gravel; and at the bottom is a sand bed probably 25 feet thick, only 12 feet of which is utilized, as the material is a little too fine for torpedo size. The normal stripping is 2 to 4 feet, but in ravines that cut down into the deposit it will run as thick as 10 feet. The gravel rarely runs larger than 3 or 4 inches and yields concrete gravel containing 50 per cent or more of crushed rock. The product goes mainly to Chicago markets.

About 1 mile south of Beloit, Wis., in Winnebago County, Ill., is situated the sand and gravel bank of the Atwood-Davis Company. This bank is on the east side of Chicago and Northwestern Railway

main line and is in the Rock river valley. The cut extends about one-third of a mile from north to south and is about 35 feet in height. The gravel is overlain by 1½ to 2 feet of black soil at the north, but to the south and east there is a bed of fine sand, 6 to 12 feet thick between the gravel and the top soil. This bed of sand forms a low ridge and also fills a shallow depression in the surface of the deposit. It is troublesome, as the sand is too fine for torpedo size and does not contain sufficient clay, except in small pockets, to make a moulding sand. Below this, gravel and gravelly sand alternate in layers 2 to 3 feet thick. The gravel ranges in size from small to medium, 4-inch pebbles being about the largest. About 15 per cent of foreign crystalline material is present in the gravel. The cut is worked to the level of the underflow in the valley, but sand and gravel are reported to extend at least 50 feet farther down, as determined by a well point. The average run of the bank, as reported by the superintendent of the pit, is about three parts of sand to two gravel. About 40 per cent of the concrete sizes produced consist of crushed gravel.

Besides the sand and gravel pits here noted, there are many small pits scattered here and there in the suburbs of Chicago worked by pick and shovel, with wagon haulage, to supply local needs. Many of these pits are in the extinct beaches of Lake Michigan, several miles from the present shore line. The location of these old beaches is shown in the areal geology maps of the Chicago geologic folio.

## GENERAL METHODS OF PREPARATION OF SAND AND GRAVEL.

The preparation of cleaned sand and gravel begins with its excavation from pit or bank, and involves moving from pit to mill, screening to separate the sand and smaller gravel, crushing to reduce the small bowlders and gravel larger than 1½ or 2 inches in diameter, and washing to free the material of silt, clay, organic matter, and depends somewhat on local conditions.

On reaching the crushing plant the gravel is screened under a stream of water. A set of screens usually comprises screens having some or all of the following sizes of perforations: 2-inch, 1½-inch, 1-inch, ¾-inch, ⅜-inch and ¼-inch. They are of both rotating and stationary types.

After the gravel and sand have been sorted by screening, crushing and washing, into the required sizes, the material is stored in bins which are readily emptied through spouts by gravity into cars on a convenient siding. By discharging two or more bins at once into the same car, and by regulating the rate of flow of sand and differently sized gravel, a mixture containing these materials in almost any desired proportion can be obtained, as, for instance, a mixture that will be suitable for concrete on the addition of the required quantity of Portland cement. During the winter months, when freezing interferes with washing operations, dry screens are use, when needed, at several plants in the district.

At the majority of plants in the district materials are separated into sizes about as follows: Torpedo sand (grains that pass ⅜-inch sieve,) roofing gravel (passing ½-inch but not ⅜-inch,) and concrete gravel (passing 1½-inch but not ½-inch.) There is some variation from

these sizes, of course, and larger sizes than 1½-inch are produced. The proportion of gravel of concrete size, which is sharp and angular as a result of crushing, depends on the coarseness of the deposit. Where the perecentage of gravel in the bank is high and a large proportion of it is more than 1½ inches in diameter, the proportion of crushed stone in the product is of course relatively high, and has been known to reach 60 per cent.

An interesting use to which the coarser gravel is put is as a flux in iron melting at Carpentersville, Ill., and this is possible because of the large percentage of dolomite pebbles in the gravel.

An important factor in the sand and gravel business is an adequate supply of water. Some plants are situated so close to Fox or Desplaines river that they may obtain water by pumping directly from the stream. Others reach an underflow at the base of the pit, or the base of the pit may be determined by water-saturated sand and gravel, and in such places an abundance of water may be obtained by driving pipes a few feet into the water-bearing gravel and pumping therefrom. Less advantageously situated with respect to water supply are those banks that are remote from a stream or high on the valley rims, but usually in this well-watered country sufficient water may be caught in reservoirs so constructed as to receive the run-off from some gully or wet-weather stream, or such a reservoir may be partly supplied by pumping or utilizing the flow of a small spring. Where conservation of water is necessary, settling basins must be constructed, and space must be provided for them. Water thus used over and over again can be kept fairly clean, but is hardly as desirable as a copious supply obtained from wells or from a clear, flowing stream such as Fox river.

## AVAILABLE SAND AND GRAVEL.

In the foregoing portion of the text suggestions have been given as to possible extensions of workings along Fox and Desplaines rivers. In review it may be said that in the valley of Fox river, from the southern part of Kenosha county, Wis., to Geneva, Ill., and perhaps farther south, there are many unworked deposits of sand and gravel. A large part of the moraines and outwash deposits left by the melting of the glaciers in southeastern Wisconsin is made up of sand and gravel. The character of these extensive deposits has been discussed in detail by William C. Alden.* Their distribution is shown on the maps accompanying his report. There are vast amounts of sand and gravel yet to be utilized in the tracts indicated. These deposits, especially the moraines, vary greatly in character, however, from point to point, and much of the material is not now readily accessible for transportation. In the Desplaines valley the best deposits are found between Joliet and the mouth of the Desplaines river. Proved but undeveloped deposits occur in the areas shown on the map forming figure 32, but owing to its necessarily small scale it has been impossible to show locations in the desired detail. On account of the irregularities in deposi-

*The Delavan lobe of the Lake Michigan glacier: Prof. Paper U. S. Geol. Survey No. 34, 1905.

tion which are common to glacial material, more particularly to morainal deposits than to outwash gravels, although somewhat characteristic of the latter, it is essential that thorough prospecting be done before arrangements are begun to work a pit or bank on a large scale. A common method of prospecting a tract is to sink a number of test wells 3 to 5 feet in diameter and as deep as desired in order to determine the thickness of cover, proportion of gravel to sand, size and character of gravel, whether or not any clay or "hardpan" is present, whether or not the materials are mixed or stratified, at what depth water is encountered, total thickness of deposit, and all such factors as have a bearing on the economical development of the deposit. In many places such test wells have to be curbed by planks to prevent the loose wall material from caving in, and often it is impossible to remove the planks from the well, so strong is the compression exerted by the deposit.

## Lake Shore Deposits.

### AVAILABLE MATERIAL.

Fine-grained sand occurs in inexhaustible quantity on the present beach of Lake Michigan, and in places there is more or less coarse sand and gravel mixed with it. As a source of supply for concrete material, however, these deposits are not now of great importance, for the following reasons: The sand is mostly of finer grain than torpedo sand, which is most desirable; the material requires special methods for the separation of sand and gravel; the deposits are constantly shifting with shore currents; and the occupancy of the lake front by docks, railroads, parks, boulevards and private grounds has made much of the beach unavailable or too valuable to be exploited for sand and gravel.

At the south end of the lake, in Indiana, sand dunes have furnished much of the filling used in track elevation, and this area, together with a few others temporarily worked south and north of Chicago, is still furnishing supplies of sand for local use, chiefly for lime mortars and plaster.

### METHOD OF OBTAINING AND PREPARATION.

At Waukegan sand and gravel are obtained in a unique manner from the beach deposit. The Waukegan Sand and Gravel Company was operating in August, 1907, a sand pump or "sand sucker" in a shallow lagoon between the Ludington Salt Company's docks and a spit occupied by the Elgin, Joliet and Eastern Railroad. The outfit consists of a centrifugal pump having a 6-inch intake and a 7-inch outlet pipe. The pump is driven by a 20-horsepower engine, and the whole apparatus is floated on a covered barge. Water, sand, and gravel as large as 3½-inch are together pumped from the bottom of the lagoon, and are discharged through a pipe of variable length into screens and thence into cars. It is possible to pump material from as great a depth as 20 feet, and to carry the delivery pipe to cars at least

600 feet distant, provided a slight fall is given the pipe. Gravel larger than 3½-inch is excluded by a screen over the mouth of the intake. Ocassionally the gravel that passes into the pump clogs it and makes trouble. It is reported that the capacity of such a plant is about 10 to 35 yards per day of ten hours.

The character of the deposits worked near Waukegan varies from place to place and also from season to season. Some deposits have been found to yield only 2 to 4 per cent of gravel, whereas others have yielded 33⅓ per cent. The material being raised at Waukegan was clean and of good quality. The gravel was composed principally of dolomite, granite, dark crystalline pebbles, quartz and chert. This material is used locally for the most part, although it is occasionally bought by Chicago dealers when an extra-clean gravel is required.

## TESTS OF MATERIALS.

It is expected to publish later the results of official tests made on the concrete materials produced in the Chicago district at the structural materials laboratories of the survey at St. Louis.

For the present paper, however, there are available an instructive set of results of tests mostly of Niagara limestone, made by the Testing Division of the Bureau of Engineering of the city of Chicago. These tests, while not made on exactly the same basis as similar tests made at the survey laboratories, are nevertheless made on a uniform basis, and afford valuable data (a) for comparison of the various samples of rock with each other; (b) for comparison of broken stone from the spoil bank of the sanitary and ship canal with freshly quarried material; (c) for comparison of gravel concrete with concrete containing crushed stone; and (d) for general information as to the strength and wearing power of the limestone.

The sampling and testing of the materials were carried on under the immediate supervision of Mr. P. C. McArdle, city engineer of tests, and the following notes in regard to the work are adapted from the report of Mr. McArdle to Mr. John Ericson, city engineer of Chicago, under date of July 30, 1907.

In order that comparative tests for strength in concrete, for strength of material itself, and for wearing should be made, samples were taken from thirty-one localities, of which fourteen were taken from the spoil bank of the Chicago drainage channel, between Willow Springs and Lockport, and the remainder were from the various quarries delivering or about to deliver crushed stone to the market.

*Preparation of Samples*—The samples for concrete were taken directly from the chutes at the crusher, of the same size as it is used in street paving and were used in that form. The samples for compression were 1 inch square by 1½ inches long, and were made by rubbing down larger blocks on an ordinary power rubbing board by an experienced stone cutter. The samples for abrasion were for the most part the size of paving blocks, 9 x 4 x3½ inches formed by the same rubbing process as the smaller pieces, and by the same operator.

Throughout the tests all samples were known by number only, and every safeguard was placed around the tests so that they might be made accurately and impartially.

*Concrete Compression Test*—The cubes used in this test were 6 inches on an edge and were formed in wooden moulds. The mixture used was the same throughout, viz., one part Whitehall Portland cement, three parts torpedo sand and six parts crushed stone. The same amount of water, 8 per cent by weight of all material, was used in each block, and material for each block was weighed out, mixed and placed separately. All blocks were made by the same man, and in as nearly as possible the same way. The test pieces were crushed under the direction of Professor Mosely, of the Lewis institute, in the presence of Mr. McArdle, using an Olsen 200,000 pound testing machine. The results of these tests are shown in the summary. The observations were made, first, when the first definite sign of failure occurred, and, second, when ultimate strength was reached. All pieces were broken at 14 days old, 48 hours of which samples set in air in molds.

These test pieces were made as nearly as possible in the same manner and of the same proportions in which the material is used for concrete foundations under asphalt, granite block, or brick street pavements.

*Compression Tests on Limestone*—These tests were all made by Mr. McArdle on a Rhiele hand power crushing machine of 20,000 pounds capacity, in the laboratory of the Bureau of Engineering at the Chicago avenue pumping station. Results as in former cases are shown in the summary. The blocks were 1 inch square by 1½ inches long generally. In this series of tests also two observations were made, one at first sign of failure, and, second, when ultimate strength was reached.

*The Abrasion Test*—This test was made on an ordinary brick rattling machine, 30 inches in diameter, 28 inches long, and in approximately the same manner as paving brick are treated. The charge consisted of fifty pounds of cast-iron blocks, 1¼ x 1¼ x 1¼ inches. The weight of stone used in nearly every case was 40 to 50 pounds. In those cases in which a loss weight had to be taken, paving brick were added to make up the weight. This test, while not to be considered as accurate as as the others, yields good general information, showing that in many cases limestone blocks stand up under the test as well as vitrified paving brick. It was impossible to get the stone all the same size or weight. The test consisted of revolving the stone blocks along with the cast iron blocks a known number of revolutions and at uniform speed. In this case 1,200 revolutions was aimed at and a speed of 37 revolutions per minute.

*Summary of Results of Tests of Limestone and Gravel Produced in Chicago District.*

By Testing Division, Bureau of Engineering, City of Chicago, July, 1907.

LIMESTONE.

| Sample No. | Furnished By. | Location. | 6-inch concrete cubes, average compressive strength, lbs. per sq. in. | 1-inch limestone cubes, average compressive strength, lbs. per sq. in. | Per cent lost by abrasion. |
|---|---|---|---|---|---|
| 1 | American Crushed Stone Co. | Sanitary canal, spoil bank, Lemont | 1,795 | 12,347 | 12.87 |
| 2 | Artesian Stone and Lime Co. | Grand and Campbell aves., Chicago | 1,850 | 11,726 | 16.07 |
| 3 | Bellewood Crushed Stone Co. | Bellewood | 1,717 | 5,721 | 21.51 |
| 4 | Brownell Improvement Co. | Thornton | 1,780 | 12,750 | 32.31 |
| 5 | Chicago Crushed Stone Co. | McCook | 1,817 | 17,600 | 13.00 |
| 6 | Consumers' Stone Co. | Lemont | 2,049 | 18,319 | 16.09 |
| 7 | Dolese & Shepherd | Gary | 1,689 | 16,300 | 16.48 |
| 8 | Dolese & Shepherd | Hawthorne | 1,605 | 9,933 | 28.51 |
| 9 | Dolese & Shepherd | McCook | 1,789 | 8,415 | 19.19 |
| 10 | Elmhurst-Chicago Stone Co. | Elmhurst | 1,669 | 15,456 | 14.41 |
| 11 | Federal Stone Co. | LaGrange | 2,192 | 8,533 | 20.00 |
| 12 | Illinois Stone Co. | Lemont | 1,847 | 12,187 | 20.50 |
| 13 | LaGrange Crushed Stone Co. | LaGrange | 2,158 | 7,937 | 20.69 |
| 14 | Parker-Washington Stone Co. | 73d st. and Yates av., Chicago | ........ | 14,696 | 18.52 |
| 15 | Sanitary District of Chicago | Canal spoil bank, sec. 2, Willow Spring | ........ | 15,725 | 42.31 |
| 16 | ..do | Canal spoil bank, sec. 3, Willow Spring | ........ | 10,371 | 14.89 |
| 17 | ..do | Canal spoil bank, sec. 4, Sag Bridge | ........ | 13,943 | 20.83 |
| 18 | ..do | Canal spoil bank, sec. 5, Sag Bridge | ........ | 11,596 | 19.30 |
| 19 | ..do | Canal spoil bank, sec. 6, Lemont | ........ | 16,100 | 17.89 |
| 20 | ..do | Canal spoil bank, sec. 7, Lemont | ........ | 11,918 | 13.64 |
| 21 | ..do | Canal syoil bank, sec. 8, Lemont | ........ | 8,883 | 15.79 |
| 22 | ..do | Canal spoil bank, sec. 11, Romeoville | ........ | 11,523 | 13.24 |
| 23 | ..do | Canal spoil bank, sec. 12, Romeoville | ........ | 13,080 | 25.45 |
| 24 | ..do | Canal spoil bank, sec. 13, Lockport | ........ | 10,886 | 32.14 |
| 25 | ..do | Canal spoil bank, sec. 14, Lockport | ........ | 6,235 | 28.51 |
| 26 | Stearnes Lime and Stone Co. | 27th and Halsted sts., Chicago | 1,918 | 10,128 | 21.43 |
| 27 | Union Limeworks Co. | 19th and Lincoln sts., Chicago | 1,511 | 11,001 | 15.46 |
| 28 | U. S. Crushed Stone Co. | McCoook | 1,802 | 8,943 | 20.19 |
| 29 | Western Stone Co. | Canal spoil bank, sec 9, Lemont | 1,934 | 11,613 | 21.74 |
| 30 | ..do | ..do | 1,808 | 11,000 | 15.31 |
| 31 | Young Stone Co. | Lemont | ........ | 16,714 | 18.37 |

GRAVEL.

| Sample No. | Furnished By. | Location. | 6-inch concrete cubes, average compressive strength, lbs. per sq. in. | 1-inch limestone cubes, average compressive strength, lbs. per sq. in. | Per cent lost by abrasion. |
|---|---|---|---|---|---|
| 1g | Lake Shore Sand Co. | Gary | 1,979 | ........ | ........ |
| 2g | ..do | ..do | 1,562 | ........ | ........ |

Analyzing the results as shown in these tests the average compressive strength on 6-inch concrete cubes of the three spoil bank samples, viz., Nos. 1, 29 and 30 yields 66,444 pounds (1,846 pounds per square inch) while the average strength of the remaining seventeen quarry samples is 64,684 (1763 pounds per square inch) nearly the same result. In the limestone compressive test the average of fourteen drainage channel spoil bank samples shows, 11,834 pounds while that from the seventeen quarry samples shows 12,397 pounds, a very slight difference.

Similarly, in abrasion test the average per cent loss of weight in the test of the fourteen drainage channel spoil bank samples is 21,00, while that of the other seventeen samples is 19.57 per cent. Eliminating, however, No. 15 the average of the thirteen remaining would be 19.36 per cent loss. The opinion of the city engineer of tests based upon these results is that the rock taken from the spoil banks is in general as good as that taken from any of the quarries of the district. Rotten stone, however, may be found in almost any of these quarries, as well as in the spoil banks, and this is particularly true of the quarries in the Lemont district, and in the spoil bank along sections 12 and 13, and this rotten stone may be readily detected by the observer.

There are submitted also tests on two samples of crushed gravel concrete, numbered 1g and 2g. The former was of large size, the latter of small size. It will be noted that No. 1g result is among the highest of all the tests made, while 2g shows a good average result.

In conclusion Mr. McArdle adds that for three years he traversed the drainage canal while it was under construction at every depth from the surface to a depth of thirty-five feet, from Lemont to Lockport, a distance of eight miles, and he unreservedly states that, with the exception of a small part of section 12 and at places in section 13, the rock while being excavated was of an exceptionally sound character; and the tests show that although the rock taken for test was necessarily taken from the outside, or weathered portion, the character still remains good, and it must reasonably be expected that on the inside of the pile also it should be sound.

## LITERATURE.

There is a long list of papers dealing with subjects mainly of purely scientific interest in connection with this area, but few of them have practical value in relation to the subject of concrete materials. In the following papers will be found useful data regarding the character and distribution of the limestone, sand, and gravel in the vicinity of Chicago:

ALDEN, WILLIAM C. Description of the Chicago district: Geologic Atlas U. S., folio 81, U. S. Geol. Survey, 1902.

——— The Delavan lobe of the Lake Michigan glacier: Prof. Paper U. S. Geol. Survey No. 34, 1905.

LEVERETT, FRANK. The water resources of Illinois: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 695-849.

——— The Pleistocene features and deposits of the Chicago area: Bull. Chicago Acad. Sci. No. 2, Geol. and Nat. Hist. Survey, 1897.

——— The Illinois glacial lobe: Mon. U. S. Geol. Survey, vol. 38, 1899.

# THE MINERAL INDUSTRY OF ILLINOIS.

(By H. Foster Bain.)

Statistics of mineral production showing the output of the State for 1906 were collected as heretofore in coöperation with the U. S. Geological Survey and a summary was published in July last.* A later summary statement was published at Washington.† The latter statement, since it includes revised figures, is reproduced below together with estimates for 1907 wherever the latter are available. Detailed figures are not yet (May 1, 1908) made up. Where no estimate is given it may be safely assumed that in 1907 the production was as large or larger than for 1906 since the intense activity of the first half of the year more than offset the depression of the latter half.

These figures are not all strictly comparable and equally accurate. They will, however, indicate the great variety and value of the mineral output of the State. In the main they represent the value of the raw material at the mines. The metals, however, except as indicated are figured on the basis of furnace product; the lead and zinc being the ore or metal produced from Illinois ore. The pig iron was all produced from ores shipped in from other states. Illinois, however, contributed the flux and much of the fuel. In accord with custom the figures are given here. The coke and by-products were only in small part produced from local materials. If, however, all material shipped in and here reduced were eliminated there would still be a gross value of $92,000,000, approximately to be credited to the mines and quarries of the State. A detailed statement will be published in Circular 4 of the State Geological Survey.

*The Mineral Production of Illinois in 1906, by F. B. Van Horn, State Geological Survey, Circular No. 2, 11 pages.

†Summary of the Mineral Production of the United States in 1906. W. Taylor Thom, Advance Chapter from the Mineral Resources of the United States, Calendar year, 1906, U. S. Geol. Survey, p. 41.

*Mineral Production of Illinois in 1906 and 1907.*

| Material. | Measure. | 1906. | | 1907. | |
|---|---|---|---|---|---|
| | | Quantity. | Value. | Quantity. | Value. |
| Cement, natural | Barrels | 356,843 | $ 118,221 | ‡375,190 | $ 174,282 |
| Cement, portland | ..do | 1,858,403 | 2,461,494 | 2,036,093 | 2,632,576 |
| Clay | Short tons | 139,704 | 131,272 | ........ | 13,351,362 |
| Clay products | ........ | ........ | 12,634,181 | | |
| Coal | Short tons | 41,480,104 | 44,763,062 | 51,317,146 | 54,687,382 |
| Coke and by-products | ........ | ........ | *3,926,103 | ........ | ........ |
| Fluorspar | Short tons | 28,268 | 160,623 | 25,128 | 141,971 |
| Glass sand | ..do | 238,178 | 156,684 | ........ | 152,619 |
| Iron, pig | Long tons | 2,156,866 | *47,128,000 | ........ | 52,228,000 |
| Lead | Short tons | 572 | 65,208 | ........ | ¶45,760 |
| Lime | ..do | 121,546 | 534,118 | ........ | ........ |
| Mineral waters | Gallons | 574,453 | 77,287 | ........ | 91,760 |
| Natural gas | ........ | ........ | 87,211 | ........ | ........ |
| Petroleum | Barrels | 4,397,050 | 3,274,818 | 24,540,024 | 16,687,216 |
| Sand and gravel | Short tons | 2,419,381 | 886,357 | ........ | 1,184,020 |
| Stone | ........ | ........ | 2,961,456 | ........ | §4,348,647 |
| Zinc, metal | Short tons | 282 | 34,404 | ........ | *6,614,608 |
| Zinc, ore | ..do | ........ | ........ | 3,517 | 57,885 |
| Pyrites | ........ | ........ | ........ | 2,000 | 5,700 |
| Other products | ........ | ........ | †1,787,807 | ........ | ........ |
| Totals | ........ | ........ | $121,188,306 | ........ | ........ |

*Estimated.
†Includes alum aluminum, sulphate, slag cent, sand-lime brick, pigments.
‡Includes slag cement.
§Includes lime.
¶Estimates of metal reduced from local ore.

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